THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. VII.

No. III.—MARCH, 1900.

ORIGINAL ARTICLES.

I.—A Contribution to Post-Glacial Geology.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

(PLATE V.)

Foraminifera of the Formby and Leasowe Marine Beds.

IN 1871 I read a paper before the Liverpool Geological Society describing the extensive and interesting submarine forests and associated Post-Glacial beds that occur fringing the coasts of Cheshire and of South-West Lancashire.[1]

The first known description of these fossil forests was in the *Gentleman's Magazine* for 1796.[2] Since then they have been described by Mr. G. H. Morton in his "Geology of the Neighbourhood of Liverpool," by the late Mr. Charles Potter, and others, and by Mr. C. E. De Rance in the Memoirs of the Geological Survey; and have formed the theme of vigorous controversy on many occasions at the meetings of the Liverpool Geological Society.

In the paper referred to it was my endeavour to describe and map out the relations of the various beds over the whole area from the mouth of the Dee to the mouth of the Ribble, and to show that they were only a part of an extensive series of beds of the same age extending round the British Isles and the opposite coasts of France and Belgium.

Since the paper was written I have had many opportunities of checking the accuracy of the work and of testing the conclusions

[1] "The Geology and Physics of the Post-Glacial Period, as shown in the Deposits and Organic Remains in Lancashire and Cheshire": Proc. Liverpool Geol. Soc., Session 1871–72, pp. 36–88, illustrated with four coloured plates of maps and sections. See also Geol. Mag., Vol. IX, pp. 111–119.

[2] Since writing the above I have found an earlier mention of them in Dr. Aikin's "Description of the Country from Thirty to Forty Miles round Manchester," published in 1795. In describing Sephton parish he says: "Along the sea-shore, and near the Grange land-mark, are the stumps of several large trees, which, by being in a line and at equal distances, were undoubtedly planted: whence it would seem as if formerly either the climate was not so rough, or the sea did not advance so far, since there would now be no possibility of raising trees in the same situation. It appears, however, as if the sea had formerly overrun a good deal of this country, from the strata of sea-slutch, moss, sand, and shells found in various parts; and the sea now again seems retiring."

arrived at. Though I might add further illustrations and facts to those already given, as indeed I purpose doing in this paper, there is very little in the original work that needs correction or alteration.

In 1897, with Professor A. Renard, of Ghent University, I had an opportunity of seeing the excavations of the new Bruges Canal near Heyst in Belgium, which resulted in my reading a paper before the Geological Society of London, in which the Microzoa, especially the Foraminifera in the silty beds overlying an extensive peat bed, are dealt with in considerable detail.[1]

So much struck was I with the similarity of these Belgian Post-Glacial deposits to those I had mapped out and sectioned in Lancashire and Cheshire, that for microscopical comparison I took the first opportunity that occurred to get specimens of the shelly blue clays underlying the Peat-and-Forest Bed in Cheshire. Mr. Joseph Wright, F.G.S., of Belfast, with his usual kindness, has examined them for me, and, I am pleased to add, extracted a most interesting assemblage of Foraminifera which form the subject of this paper. It will be observed that the Belgian beds referred to occur above the main bed of peat, whereas those in Cheshire and Lancashire occur below the superior peat bed. The synchronism of the beds will be discussed later on.

The Superior Peat-and-Forest Bed is exposed in a continuous section along the shore from the west end of the old Wallasey Embankment to a spot between Dove Point and Hoylake. Many stools of trees rooted in the clay and silt below are still to be seen, but the whole bed has been much reduced in area by the denudation of the sea since my survey of 1871 was made. The peat has also been stripped off, so that where formerly it was several feet thick it is now reduced sometimes to one foot or less. Underlying this Upper or Superior Peat-and-Forest Bed is a blue silty clay, which is now nowhere exposed for a greater depth than from two to three feet. It is this clay which I have classed with a similar bed in Lancashire under the name of the Formby and Leasowe Marine Beds, and from which the specimens yielding Foraminifera were taken. At places there are still some exposures of a second bed of peat underlying the Formby and Leasowe bed. This bed is known as the Lower or Inferior Peat-and-Forest Bed, and it in turn rests upon the Boulder-clay which is also exposed in the western end of the series of beds described. I may add that this series is the thinned-out shore margin of these Post-Glacial deposits.

Description of Specimens.

Specimen No. 1 was taken about a quarter of a mile east of Dove Mark from the blue silt lying between the Superior Peat-and-Forest Bed, which is here about 1 foot thick, and the Inferior Bed, here only a few inches thick. The blue silt (Formby and Leasowe Marine Beds) was only 2 feet thick, and contained much vegetable matter in the shape of traversing fibres. Below the Inferior Peat

[1] "Post-Glacial Beds exposed in the Cutting of the New Bruges Canal": Q.J.G.S., vol. liv (1898), pp. 575–581.

was a bed of bluish clay about 7 inches thick, full of pebbles, many of which were glacially facetted. This was evidently the redistributed Boulder-clay derived from the brown Boulder-clay on which it rested, which was only exposed about 6 inches in depth.

Specimen 2 was taken from this brown Boulder-clay, but it was only a surface specimen, much perforated by rootlet tubes.

It will be seen from this description that the paucity of Foraminifera in specimens Nos. 1 and 2 is not surprising.

Specimens Nos. 3 and 4 were taken from the blue clay (Formby and Leasowe Marine Beds) a little west of the west end of the old Wallasey Embankment, at a depth of 18 inches below the Superior Peat and horizontally about 20 feet apart. Here were found numerous specimens of *Scrobicularia piperata*, vertical as in life, with both valves united but in a very chalky condition. This was a good representative of the *Scrobicularia* Clay of the Formby and Leasowe Marine Beds, and yielded Foraminifera in profusion.

No. 5 is a specimen of brown Boulder-clay taken between Dove Point and Hoylake at a greater depth than specimen No. 1; the capping of redistributed blue clay and pebbles and Inferior Peat and Forest Bed was more developed, and good-sized roots traversed them, striking into the Boulder-clay below. This was an outlier of the Inferior Peat-and-Forest Bed, the Superior Peat and Formby and Leasowe Beds appearing on a higher level of the shore immediately opposite the outlier. Mr. Wright's report shows that notwithstanding the shallow depth at which the specimen of Boulder-clay was taken it contained eleven species of Foraminifera. The relations between these Glacial Foraminifera and the Post-Glacial forms will be discussed later on.

Report by Mr. Joseph Wright, F.G.S.

No. 1, from between upper and lower peat beds, Leasowe Shore. Weight of clay, 15·8 oz. troy. After washing, ·8 oz. fine; no coarse. Clay very fine and containing a large quantity of vegetable matter. Only one Foraminifer was obtained; it was a weak specimen of *Trochammina inflata*.

No. 2. Brown Boulder-clay, under lower peat. Weight of clay, 18·4 oz. troy. After washing, 2·8 oz. fine; ·6 coarse. Most of the stones more or less rounded, one of them showing faint striæ. Clay containing a large quantity of vegetable matter. Foraminifera very rare, only three specimens of *Polystomella striato-punctata*.

No. 3. Blue clay with *Scrobicularia in sitû*. Weight of clay, 17·8 oz. troy. After washing, ·56 oz. fine; ·01 coarse. Fragments of shells only. Clay containing a quantity of vegetable matter. Foraminifera most abundant.

FORAMINIFERA.

* *Miliolina seminulum* (Linné). One specimen.
Cornuspira involvens, Rss. One specimen.
* *Trochammina inflata* (Montag.). Very common. (Pl. V, Fig. 1.)
* *Textularia globulosa*, Ehr. Frequent. (Pl. V, Fig. 2.)

* *Bulimina pupoides*, D'Orb. Common. (Pl. V, Fig. 3.)
,, *marginata*, D'Orb. Rare. (Pl. V, Fig. 4.)
,, *fusiformis*, Will. Frequent. (Pl. V, Fig. 5.)
* ,, *elegantissima*, D'Orb. Very common. (Pl. V, Fig. 6.)
* *Bolivina punctata*, D'Orb. Very common. (Pl. V, Fig. 10.)
* ,, *plicata*, D'Orb. Very common. (Pl. V, Fig. 7.)
,, *lævigata* (Will.). Very rare.
,, *difformis* (Will.). Rare.
,, *dilatata*, Rss. Frequent.
* ,, *obsoleta*, Eley. Very rare. (Pl. V, Fig. 8.)
,, ,, var. *serrata*, Nov. Frequent. (Pl. V, Fig. 9.) This form differs from *B. obsoleta* in the segments being more obliquely set, and in the marginal ends projecting, especially in the later segments; specimens very small.
* *Cassidulina crassa*, D'Orb. Very common. (Pl. V, Fig. 11.)
* *Lagena globosa* (Montag.). Rare.
* ,, *lævis* (Montag.). Frequent. (Pl. V, Fig. 12.)
* ,, *clavata* (D'Orb.). Frequent. (Pl. V, Fig. 13.)
* ,, *sulcata* (W. & J.). Very rare. (Pl. V, Fig. 14.)
,, *semistriata*, Will. Frequent.
* ,, *hexagona* (Will.). Rare. (Pl. V, Fig. 15.)
* ,, *squamosa* (Montag.). One specimen.
* ,, *lævigata* (Rss.). Very common.
* ,, *lucida* (Will.). One specimen.
* ,, *Orbignyana* (Seg.). Very rare.
* ,, *marginata* (W. & B.). Very common. (Pl. V, Fig. 17.)
* *Nodosaria communis*, D'Orb. Rare, fragments.
,, *pyrula*, D'Orb. Rare, fragments.
Rhabdogonium tricarinatum, D'Orb. Very rare.
Cristellaria rotulata (Lamk.). Rare.
* ,, *crepidula* (F. & M.). One specimen. (Pl. V, Fig. 16.)
* *Polymorphina lactea* (W. & J.). Very rare.
Uvigerina Canariensis, D'Orb. Very rare.
* ,, *angulosa*, Will. Very common.
* *Globigerina bulloides*, D'Orb. Very common. (Pl. V, Fig. 18.)
* ,, *cretacea*, D'Orb. Very common. (Pl. V, Fig. 19.)
* *Orbulina universa*, D'Orb. Very common.
Spirillina vivipara, Ehr. Very rare.
* *Patellina corrugata*, Will. Very rare. (Pl. V, Fig. 20.
* *Discorbina globularis* (D'Orb.). Rare. (Pl. V, Fig. 21.)
* ,, *rosacea* (D'Orb.). Very common.
* ,, *Wrightii*, Brady. Very common.
* *Truncatulina lobatula* (W. & J.). Frequent.
* *Pulvinulina*, sp. near *P. auricula* (F. & M.). Rare.
* *Rotalia Beccarii* (Linné). Very common. (Pl. V, Fig. 22.
* *Nonionina depressula* (W. & J.). Most abundant. (Pl. V, Fig. 23.)
,, *pauperata*, B. & W. Frequent.
,, *turgida*, Will. (?). One broken specimen.
* *Polystomella striato-punctata* (F. & M.). Most abundant. (Pl. V, Fig. 24.)
Ostracods common.

In this clay medium-sized specimens both of *Nonionina depressula* and *Polystomella striato-punctata* are in great profusion and in fine preservation, the other Foraminifera being for the greater part small or very small in size. The Arenacea are represented only by *Trochammina inflata*, some of the specimens being large in size; and only two specimens of the Porcellanea were obtained, viz., one each of *Miliolina seminulum* and *Cornuspira involvens*.

No. 4. Blue clay with *Scrobicularia in sitû* taken 18 inches below upper peat. Weight of clay, 31·2 oz. troy. After washing, ·8 oz.

fine; ·008 oz. coarse fragments of shells only. Clay containing a quantity of vegetable matter. Foraminifera most abundant.

FORAMINIFERA.

* *Miliolina seminulum* (Linné). One specimen.
Reophax scorpiurus, Montf. One small specimen.
Haplophragmium Canariense (D'Orb.). One specimen.
Trochammina squamata, J. & P. One small specimen.
* ,, *inflata* (Montag.). Very rare.
* *Textularia globulosa*, Ehr. Common.
Gaudryina filiformis, Berth. One specimen.
* *Bulimina pupoides*, D'Orb. Very common.
,, *marginata*, D'Orb. Frequent.
,, *fusiformis*, Will. Common.
* ,, *elegantissima*, D'Orb. Very common.
Virgulina Schreibersiana, Cz. Very rare.
* *Bolivina punctata*, D'Orb. Very common.
* ,, *plicata*, D'Orb. Very common.
,, *lævigata* (Will.). Rare.
,, *difformis* (Will.). Common.
,, *dilatata*, Rss. Frequent.
* ,, *obsoleta*, var. *serrata*, Nov. Frequent.
Cassidulina lævigata, D'Orb. Rare.
* ,, *crassa*, D'Orb. Very common.
* *Lagena globosa* (Montag.). Common.
* ,, *lineata* (Will.). Frequent.
* ,, *lævis* (Montag.). Common.
* ,, *clavata* (D'Orb.). Common.
* ,, *sulcata* (W. & J.). Common.
* ,, *Williamsoni* (Alcock). Very rare.
,, *striata* (D'Orb.). Rare.
,, *semistriata*, Will. Rare.
* ,, *squamosa* (Montag.). One specimen.
* ,, *hexagona* (Will.). Frequent.
* ,, *lævigata* (Rss.). Very common.
,, *lucida* (Will.). Frequent.
,, *quadrata* (Will.). Very rare.
* ,, *marginata* (W. & B.). Very common.
* ,, *bicarinata* (Terq.). One specimen.
* ,, *Orbignyana* (Seg.). Rare.
,, *lagenoides* (Will.). Very rare.
,, *clathrata*, Br. Elongate pyriform variety. One small specimen.
Nodosaria radicula (Linné). Very rare.
,, *calomorpha*, Rss. Very rare.
,, *pyrula*, D'Orb. Very rare.
* ,, *communis*, D'Orb. Very rare.
,, *obliqua* (Linné). Very rare.
Rhabdogonium tricarinatum, D'Orb. Rare.
Cristellaria rotulata (Lamk.). Very common.
* ,, *crepidula* (F. & M.). Rare.
* *Polymorphina lactea* (W. & J.). Rare.
Uvigerina Canariensis, D'Orb. Very rare, specimens broken.
* ,, *angulosa*, Will. Very common.
* *Globigerina bulloides*, D'Orb. Very common.
* ,, *cretacea*, D'Orb. Very common.
* *Orbulina universa*, D'Orb. Very common.
Spirillina vivipara, Ehr. One small specimen.
* *Patellina corrugata*, Will. Rare.
* *Discorbina globularis* (D'Orb.). Rare.
* ,, *rosacea*, D'Orb. Very common.
* ,, *Wrightii*, Brady. Very common.

Discorbina tuberculata, B. & W. Very rare.
* *Truncatulina lobatula* (W. & J.). Very common.
Pulvinulina Karsteni (Rss.). Rare.
* ,, sp. near *auricula* (F. & M.). Rare.
* *Rotalia Beccarii* (Linné). Very common.
* *Nonionina depressula* (W. & J.). Most abundant.
,, *pauperata*, B. & W. Common.
,, *turgida*, Will. Very rare.
,, *stelligera*, D'Orb. Rare.
* *Polystomella striato-punctata* (F. & M.). Most abundant.

Ostracods very common.

The Foraminifera in this gathering are very similar to those obtained from the previous sample (No. 3). Medium-sized specimens of *Rotalia Beccarii*, *Nonionina depressula*, and *Polystomella striato-punctata* occur in great profusion, the other species being for the greater part small or very small in size.

No. 5. Boulder-clay. Weight of clay, 28 oz. troy. After washing, 2·6 oz. fine; ·65 oz. coarse. The greater portion of the stones more or less rounded. Foraminifera frequent.

FORAMINIFERA.

Miliolina seminulum (Linné). One specimen.
Bolivina plicata, D'Orb. Very rare.
Cassidulina crassa, D'Orb. Very rare.
Lagena sulcata (W. & J.). One specimen.
,, *lævigata* (Rss.). Very rare.
Cristellaria rotulata (Lamk.). One specimen.
Globigerina bulloides, D'Orb. One specimen.
Discorbina rosacea (D'Orb.). One specimen.
Rotalia Beccarii (Linné). One specimen.
Nonionina depressula (W. & J.). Common.
Polystomella striato-punctata (F. & M.). Frequent.

The species marked with an asterisk occur in one or other of the Heyst deposits of the new Bruges Canal, viz. the "Argile des polders supérieure," the "*Cardium* Sand," or the "*Scrobicularia plana* (*piperata*) Clay." Some of the Boulder-clay forms also occur in the Heyst deposits, but these are not marked, as it is wished to confine the comparison to beds of the same age.

A comparison of this list of Foraminifera, consisting of 68 species in all, with that of the Bruges beds already referred to, shows that there are 34 or half of the species in common. *Globigerina cretacea*, a notable form which is common to both, does not occur as a recent species in the British Isles, and in consequence Mr. Wright thought that those in the Bruges silts were not native to the deposits, but derived from Cretaceous beds in the neighbourhood. The discovery of *Globigerina cretacea* in abundance in the Leasowe under-clay shows that the species are here indigenous, as there are no Cretaceous beds in Cheshire or adjoining counties from which they could be derived.

Mr. Wright also observes that the interiors of Foraminifera from our Chalk are filled with silica, so that when placed in muriatic acid

the tests of the shells only are affected by it, the casts being unaltered. On placing some of the Leasowe specimens in the acid they all effervesced away, showing that they could not have been derivative from the Chalk, and must have lived where now found. On testing the Bruges specimens with acid the same thing happened with no siliceous remainder, so that I think Mr. Wright is justified in now thinking that this species was living where found in the Bruges sand and silt.

Textularia globulosa is a form very rare in British waters, but common in the Chalk, occurs in abundance in the Leasowe Beds, and also in the Bruges silt. *Globigerina cretacea* was found rare in the Boulder-clay at Riverside, Seacombe, Cheshire, and *Textularia globulosa* very rare in the Crosby Boulder-clay. (See Proc. Liverpool Geol. Soc., vol. viii, session 1898–99, p. 361, and ibid., vol. vii, session 1895–96, p. 389.)

The Post-Glacial Deposits represent a well-marked Geological Episode.

As I have proved in many previous papers,[1] these marginal beds around our Island contain records of several oscillations of the level of the land, cumulatively giving evidence of a well-marked period of time between the dying out of the Glacial epoch and the incoming of historic time.

It is well worthy of note that the deposits bear a characteristic physical resemblance to each other, whether found in England, Scotland, Ireland, or Belgium, being evidence of the widespread and persistent nature of the conditions under which they were laid down. The fauna and flora are analogous, and we further find the silts associated with *Scrobicularia piperata* are distinguished by the presence of *Globigerina cretacea*, a species of Foraminifera not now found living in the British Isles. The peat-and-forest beds show that our Island was covered with forest trees, of which this marginal band has been preserved by being covered up with a growth of peat and deposits of silt, sand, and blown sand. There is good evidence that the climate of this period was milder and more continental than the present one.

It may be noted as interesting that the royal fern, *Osmunda regalis*,[2] is found in the superior peat at the Alt mouth, and also what is not uncommon in peat beds, viz. the wing

[1] See papers previously referred to; also many minor papers in the Proceedings of the Geological Society of Liverpool, and the following: "A Problem for Irish Geologists in Post-Glacial Geology," Journ. Roy. Geol. Soc. Ireland, N.S., vol. ii, pt. 4, pp. 255–258; "Oscillations in the Level of the Land as shown by the Buried River-Valleys and Later Deposits in the Neighbourhood of Liverpool," GEOL. MAG., 1896, pp. 488–492. As bearing upon the same subject, see also an excellent paper by Mr. A. Strahan, "On Submerged Land Surfaces at Barry, Glamorganshire," with notes on the Fauna and Flora by Mr. Clement Reid: Q.J.G.S., vol. lii (1896), pp. 474–496.

[2] I showed this fern embedded in the peat to the members of an excursion party of Section C at the twenty-fourth meeting of the British Association at Liverpool, 1896.

cases of beetles. When the Post-Glacial deposits rest on Boulder-clay, as is commonly the case, and a section displays both, the difference of the deposits are so striking that a novice may at once pronounce upon them. It is noticeable that the surface of the Boulder-clay under the Post-Glacial deposits is deeply eroded by subaerial action, indicating that the land was at that time at a higher level than now with respect to the sea. The silt and *Scrobicularia* clays containing the profusion of Foraminifera detailed in the preceding lists are equally a sign of the subsequent submergence of this Boulder-clay surface to a depth marked generally by the 25 feet contour-line. The Superior Peat-and-Forest Bed is again a sign of following subaerial conditions succeeded by a depression, for much of it is now washed over by the tides.

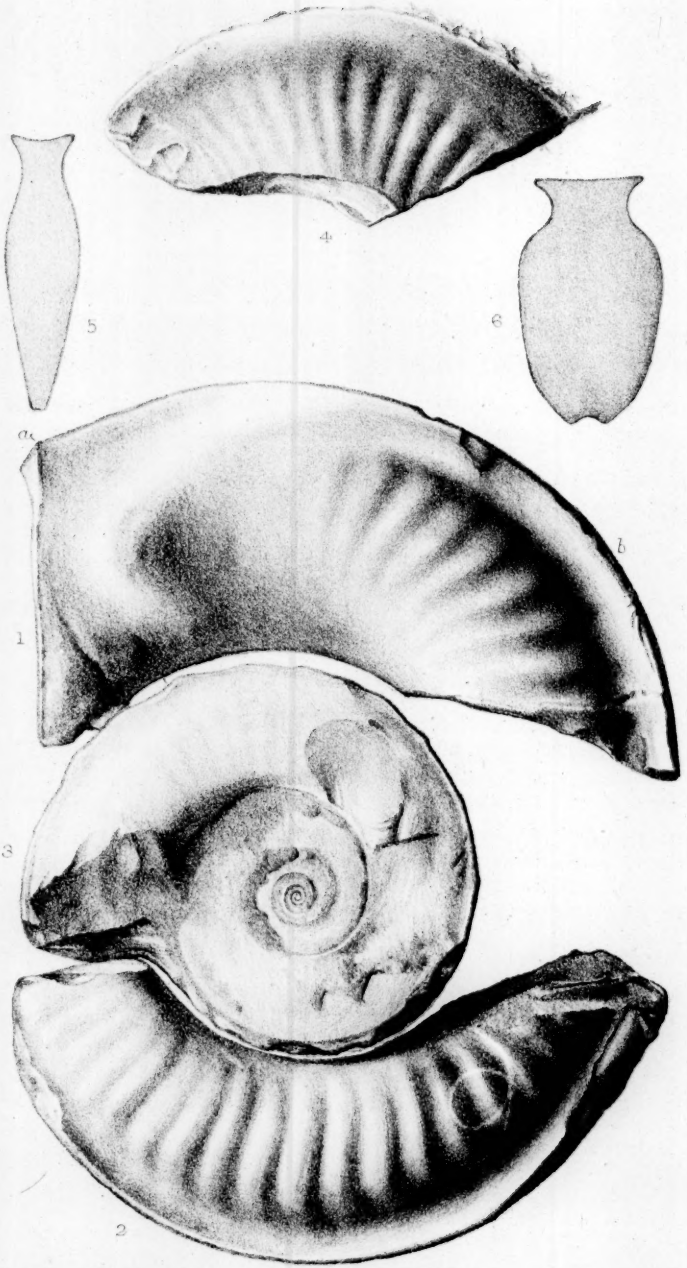
The last movement of the land was downwards at Formby and Leasowe, and it appears to me to have been the same in Belgium. As I have before observed, the Bruges Canal or Heyst silts lie above the peat, whereas the Leasowe silts lie below. If the Heyst peat is of the same age—and it is certainly not older than the Superior Peat-and-Forest Bed at Leasowe—the Belgian silts I have described are not so old as those at Leasowe, but they nevertheless belong to the same series of beds.[1] This group of beds is a geological object-lesson of a comparatively recent date, showing that geological periods are records of a similar kind, but on a larger scale of widely prevailing physical conditions.

Relative to these conditions it is interesting to find that the Boulder-clay on which the group rests, though so markedly different in physical constitution, possesses a foraminiferal fauna of much the same character, though of a more stunted growth. Even in this little surface exposure one of the specimens of Boulder-clay yielded eleven species of Foraminifera, and if it were possible to get specimens from a depth of 10 or 20 feet it would no doubt yield them in the same profusion as the Boulder-clay at Great Crosby, Lancashire, or Riverside, Seacombe, Cheshire.[2] The species found in the Leasowe Beds have doubtless lived through the Glacial seas, nevertheless the two periods or episodes are so physically different that no geologist could mistake one for the other.

The artistic figures given in the Plate accompanying this paper are by Mr. Robert Welsh, of Belfast, and I am greatly indebted to him and Mr. Wright for enabling me to illustrate the leading species in such a satisfactory manner. Being photographs of the actual specimens obtained from the Leasowe deposit, they are instructive as showing the relative sizes of the different species as they occur in the deposit.

[1] There is a very good engineering description of the works of the new Bruges Ship Canal by Mr. Vernon Harcourt in the Minutes of Proceedings of the Institute of Civil Engineers, vol. cxxxvi (1899), pp. 283–295, with plans and sections.

[2] "The Gypsum Boulder, Great Crosby": Proc. Liverpool Geol. Soc., 1898–99, pp. 347–356. "Foraminiferal Boulder-clay, Riverside, Seacombe, Cheshire": ibid., pp. 357–364.



G.M.Woodward del. et lith. West, Newman imp.

Pleuronautilus? scarlettensis. *sp. nov.*
Carboniferous, I. of Man.

EXPLANATION OF PLATE V.

FIG. 1. *Trochammina inflata* (Montag.).
,, 2. *Textularia globulosa*, Ehr.
,, 3. *Bulimina pupoides*, D'Orb.
,, 4. ,, *marginata*, D'Orb.
,, 5. ,, *fusiformis*, Will.
,, 6. ,, *elegantissima*, D'Orb.
,, 7. *Bolivina plicata*, D'Orb.
,, 8. ,, *obsoleta*, Eley.
,, 9. ,, ,, var. *serrata*, Nov.
,, 10. ,, *punctata*, D'Orb.
,, 11. *Cassidulina crassa*, D'Orb.
,, 12. *Lagena lævis* (Montag.).
FIG. 13. *Lagena clavata* (D'Orb.).
,, 14. ,, *sulcata* (W. & J.).
,, 15. ,, *hexagona* (Will.).
,, 16. *Cristellaria crepidula* (F. & M.).
,, 17. *Lagena marginata* (W. & B.).
,, 18. *Globigerina bulloides*, D'Orb.
,, 19. ,, *cretacea*, D'Orb.
,, 20. *Patellina corrugata*, Will.
,, 21. *Discorbina globularis* (D'Orb.).
,, 22. *Rotalia Beccarii* (Linné).
,, 23. *Nonionina depressula* (W. & J.).
,, 24. *Polystomella striato-punctata* (F. & M.).

The figures are magnified 40 diameters.

II.—Woodwardian Museum Notes: A new Carboniferous Cephalopod, *Pleuronautilus*? *scarlettensis*, sp. nov.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE VI.)

FOUR fragments of a large cephalopod (from the Carboniferous Limestone) were collected by Professor Hughes' party in 1892 at Scarlett Quarry, Isle of Man. On fitting three of these together they were found to compose nearly the complete shell, and in a sufficiently good state of preservation to warrant description. The fourth fragment is a cast of a portion of the external surface. Mr. G. C. Crick has expressed his opinion that they represent a new species and probably a new subgenus or genus.

Diagnosis.—Shell discoidal, compressed; whorls in contact, but not overlapping; umbilicus wide, shallow, exposing all the whorls; no central vacuity; volutions rapidly increasing in width. Whorls eight in number, laterally compressed and flattened, twice as high as broad. The two outer whorls form nearly four-fifths the diameter of the shell, and have steeply sloping walls to the umbilicus. The outer whorl has its sides weakly convex for the inner two-thirds of its width and crossed by about thirty transverse rounded plications, which are strongest about the middle portion of the whorl, but become gradually weaker towards the beginning of the second whorl, and also towards the aperture, dying out completely a short distance from it. The outer fourth of this whorl is not crossed by these plications, but is deeply excavated into a broad marginal groove bordered by the sharp edge of the ventral side. Ventral (peripheral) side rather less in width than diameter of whorl, flattened or slightly concave with projecting edges overhanging the marginal groove on the sides. Dorsal side narrow, about one-fourth the width of ventral side, marked by shallow groove where in contact with next whorl. Second whorl with very weak or obsolete transverse plications, and the marginal groove very shallow and gradually dying out. Inner whorls poorly preserved, but with nearly flat sides, devoid of transverse plications and marginal groove. Aperture vertical, narrow, lanceolate, with sides produced obliquely forwards to ventral rostrum. The sides of

the outer whorl near the aperture become slightly swollen, and then are suddenly depressed to the level of the marginal groove, the ventral side at the same time considerably narrowing and losing its overhanging edges and being produced apparently into a pointed rostrum. Septa, sutures, and siphuncle not preserved.

Measurements.—Diameter of shell, 13″–15″; height of mouth, $4\frac{1}{2}$″; width of ditto, $1\frac{1}{4}$″.

Remarks.—The only species which has a general resemblance in possessing transverse plications and an overhanging concave ventral side is *Gyroceras* (*Trigonoceras*) *aigoceras* (Münster),[1] but as it consists of only two whorls, which are not in contact, are of much greater breadth, and have a sharp keel-like dorsal side, the resemblance is not very close. Moreover, so far as we know, the mouth did not possess the important features which we find in the Manx form. There is no species of *Gyroceras* with which I am acquainted exhibiting these characteristics, and it seems impossible to attribute our new form to this genus or to *Discites*. *Pleuronautilus* has a closely coiled shell with transverse ribs; but, on the other hand, a rather large central perforation is present. Mojsisovics[2] has remarked on the relations between *G. aigoceras* and *Pleuronautilus*, and it seems advisable for the present to place our new form in the latter genus, though probably a subgenus or genus will have to be made to contain it (which might appropriately receive the name of *Euboniceras* from the ancient name of the Isle of Man). Until we know the suture-lines, septa, and siphuncle it will, however, be wiser to associate it with *Pleuronautilus*.

EXPLANATION OF PLATE VI.

Pleuronautilus? scarlettensis, sp. nov. Carboniferous Limestone: Scarlett Quarry, Isle of Man. One-third nat. size.

1. Body-chamber of shell.
2. Part of outer whorl.
3. Inner whorls of shell.
4. Cast of surface.
5. Transverse section of Fig. 1 near the mouth at *a*.
6. Transverse section of Fig. 1 at *b*.

III.—On some Minor British Earthquakes of the Years 1893–1899.

By Charles Davison, Sc.D., F.G.S.

During the seven years 1893–1899, 42 earthquakes have been felt in Great Britain—28 in England and Wales and 14 in Scotland.[3] All of the latter number visited areas which are thinly populated, and it has therefore been impossible to draw the boundaries with the accuracy that is to be desired. In the English earthquakes this

[1] Münster, "*Cyrtoceras aigokeros* (1838)": Beitr. r. Petrefact., 2nd ed., Heft i (1843), p. 56, t. i, figs. 7*a*, 7*b*; t. ii, fig. 1. Foord: Cat. Foss. Ceph. Brit. Mus., pt. ii (1891), p. 72, and references.

[2] "Die Ceph. d. Medit. Triasprov.": Abhandl. d. k. k. geol. Reichs., Bd. x (1882), p. 73.

[3] The cost of investigating all these earthquakes was defrayed from grants which I had the honour to receive from the Government Research Fund.

difficulty is seldom encountered, and the failures are generally due to the confusion caused by the rather rapid succession of the shocks.

The number of earthquakes more or less briefly described in this paper is 19, and, with few exceptions, I have not been able to correlate them with known faults. It should not be inferred from this that the shocks owe their origin to some other cause than fault-slipping; for, in nearly every case, the epicentral region is one in which it is difficult to detect faults. It is possible, indeed, that the careful study of an earthquake may form a useful supplement to the methods which are at the disposal of the field-geologist.

Explanation of Map-Symbols.—In a weak earthquake, every place of observation can generally be marked on the map; and, without making use of a wide range of symbols, it is convenient to employ signs to represent the perception of the shock and sound. In all but one of the following maps, a square indicates that the shock was felt, a triangle that no mention is made of the shock or that its perception was doubtful, and a circle that no shock was felt. A figure entirely filled in denotes that the sound was heard, one half-filled in that no mention is made of the sound or that its perception was doubtful, and one not filled in at all that no sound was heard.

List of Earthquakes, 1893–1899.

1893, Jan. 2, 7.20 p.m. Glen Garry.
Aug. 3, 6.41 p.m. Leicester.
Nov. 2, 5.45 p.m. Pembroke (principal earthquake).
,, 6.1 p.m. Pembroke.
,, about 6.15 or 6.20 p.m. Pembroke.
Nov. 3, about 1 a.m. Pembroke.
Dec. 11, about 3 p.m. Glen Garry.
Dec. 30, 11.20 p.m. Somerset.
Dec. 31, 12.28 a.m. Somerset.
,, about 4 a.m. Somerset.
1894, Jan. 12, about 11.55 p.m. Fort William.
Jan. 23, about 9 a.m. Exmoor.
Jan. 25, 1.7 p.m. Glen Garry.
March 8, about midday. Annandale.
May 14, in the afternoon. Annandale.
July 12, about 11 p.m. Comrie.
Sept. 18, 10.10 a.m. Glen Garry.
1895, Jan. 9, about 5.45 a.m. Fort William.
July 12, about 7.40 a.m. Comrie.
Aug. 27, about 12.30 p.m. Cornwall.
1896, Jan. 26, 6.50 a.m. Cornwall.
May 29, 4.47 a.m. Annandale.
June 5, early in the morning. Glen Nevis.
Dec. 16, about 11.0 or 11.30 p.m. Hereford.
Dec. 17, ,, 1 a.m. Hereford.
,, ,, 1.30 or 1.45 a.m. Hereford.

1896, Dec. 17, about 2 a.m. Hereford.
„ „ 3 a.m. Hereford.
„ „ 3.30 a.m. Hereford.
„ „ 4 a.m. Hereford.
„ „ 5 a.m. Hereford.
„ „ 5.20 a.m. Hereford.
„ 5.32 a.m. Hereford (principal earthquake).
„ about 5.40 or 5.45 a.m. Hereford.
„ „ 6.15 a.m. Hereford.
1897, July 19, 3.49 a.m. Hereford.
1898, Jan. 28, about 10.5 p.m. Rutland.
Mar. 29, about 10.25 p.m. Cornwall.
Apr. 1, 9.55 p.m. Cornwall.
Apr. 2, about 3 p.m. Cornwall.
Aug. 22, about 7.15 a.m. Comrie.
1899, Dec. 18, about 6.50 a.m. Glen Garry.

The more important of these earthquakes have been described in the following papers, etc. :—

"On the Leicester Earthquake of August 4, 1893": Roy. Soc. Proc., vol. lvii, 1895, pp. 87–95.

"On the Pembroke Earthquakes of August, 1892, and November, 1893": Quart. Journ. Geol. Soc., vol. liii, 1897, pp. 157–175.

"On the Exmoor Earthquake of January 23, 1894, and on its Relation to the Northern Boundary Fault of the Morte Slates": Geol. Mag., Vol. III, 1896, pp. 553–556.

"On the Comrie Earthquake of July 12, 1895, and on the Hade of the Southern Boundary Fault of the Highlands": Geol. Mag., Vol. III, 1896, pp. 75–79.

"The Hereford Earthquake of December 17, 1896." (Cornish Brothers, Birmingham, 1899.)[1]

"On the Cornish Earthquakes of March 29th to April 2nd, 1898": Quart. Journ. Geol. Soc., vol. lvi, 1900, pp. 1–7.

[1] Since this report was written, several papers have been published on the Hereford earthquake. The following is a complete list of those which I have seen :—

W. Cole, "The English Earthquake of December 17th, 1896": Essex Nat., vol. ix, 1896, pp. 258–259. (Records from Essex.)

H. G. Fordham, "The Earthquake of the 17th December, 1896, as it affected the County of Hertford": Herts. Nat. Hist. Soc. Trans., vol. ix, 1897, pp. 183–208. (Records from Hertfordshire and adjoining counties.)

E. Greenly, "The Hereford Earthquake of December 17, 1896, considered in relation to Geological Structure in the Bangor-Anglesey Region": Edin. Geol. Soc. Trans., vol. vii, 1898, pp. 469–476.

J. Lomas, "The Earthquake of December 17th, 1896": Liverpool Geol. Soc. Proc., 1896–1897, pp. 91–98. (Records from the neighbourhood of Liverpool chiefly.)

H. C. Moore, R. Clarke, & A. Watkins, "The Earthquake of December 17th, 1896": Woolhope Field Club Trans, 1898 (?), pp. 1–8. (A detailed account of the damage to buildings in Herefordshire.)

G. J. Symons, "The Earthquake of December 17th, 1896": Meteor. Mag., vol. xxxi, 1896, pp. 177–185. (An analysis chiefly of newspaper reports.)

Rev. H. H. Winwood, "Notes and Observations on the Earthquake of December the 17th, 1896," contributed by members of the Cotswold Club: Cotswold Nat. Field Club Proc., vol. xii, 1896–1897, pp. 187–196. (Records from Gloucestershire.)

Glen Garry Earthquake: Jan. 2, 1893.

A slight shock, accompanied by a noise as of a carriage passing very rapidly, was felt by Mr. Duncan Grant at Glenquoich at 7.20 p.m. The noise was also heard by another observer about three miles higher up the Glen.

Glen Garry Earth-Sound: Dec. 11, 1893.

A low rumbling sound, resembling that which accompanies an earthquake, was heard at about 3 p.m. at Glenkingie, Glenquoich, and Lochournhead. There was no perceptible movement of the ground.

This note is founded on a paragraph in the *Oban Times* for Dec. 15 (?).

Somerset Earthquakes: Dec. 30–31, 1893.

The number of earthquakes that should be included in this series is somewhat uncertain. The most important are those which occurred on Dec. 30 at 11.20 p.m. and on Dec. 31 at 12.28 a.m., and these were followed at about 4 a.m. by a third but much weaker shock. There may also have been four others in the early morning of Dec. 31, but the times are only roughly recorded, and they ought, I think, to be regarded as doubtful earthquakes. They are as follows:—

a. Shepton Mallet, shortly after the shock at 12.28; and Draycot, 12.45 or 12.50 a.m.

b. Shepton Mallet, between 1 and 2 a.m.; and Wedmore, about 1.30 a.m.

c. Croscombe, about 2.30 a.m.; and Wookey, about 2.15 a.m.

d. Street, 2 or 3 minutes after the shock at about 4 a.m.

The times of the two principal shocks were determined by a signalman at Masbury station, and, as they agree with those given by several other witnesses, they are no doubt correct to the nearest minute.

For convenience, the isoseismal lines of both earthquakes are shown upon one map (Fig. 1), and the symbols referred to above are therefore not employed. Also, as it would be difficult to represent all the places of observation on so small a figure, I have only marked those which are of importance or which are mentioned in the following pages. The broken lines refer to the first earthquake, the continuous lines to the second.

First Earthquake: Dec. 30, 11.20 *p.m.*—The number of records is 45, coming from 27 places. There are also negative records from 20 places; and, in addition, two observations from Frome and Whatley, the connection of which with the present shock is doubtful.

The intensity of the shock was certainly not less than 4, and at Wells may have been as high as 5. The disturbed area is $15\frac{1}{2}$ miles long, $13\frac{1}{4}$ miles broad, and contains 159 square miles. Owing to the absence of negative records towards the north-west, it is uncertain whether the boundary should not extend a little further outwards on this side. The direction of its longer axis is W. 30° N. and E. 30° S. Its centre lies $\frac{1}{2}$ mile S. 37° W. of Wells.

The isoseismal 4 is an elongated oval, 9½ miles long, 5 miles broad, and 38 square miles in area. The direction of its longer axis is W. 30° N. and E. 30° S.; and its centre is one mile N. 35° W. of Wells. The distance between the two isoseismals is 3 miles on the north-east side and 5 miles on the south-west side.

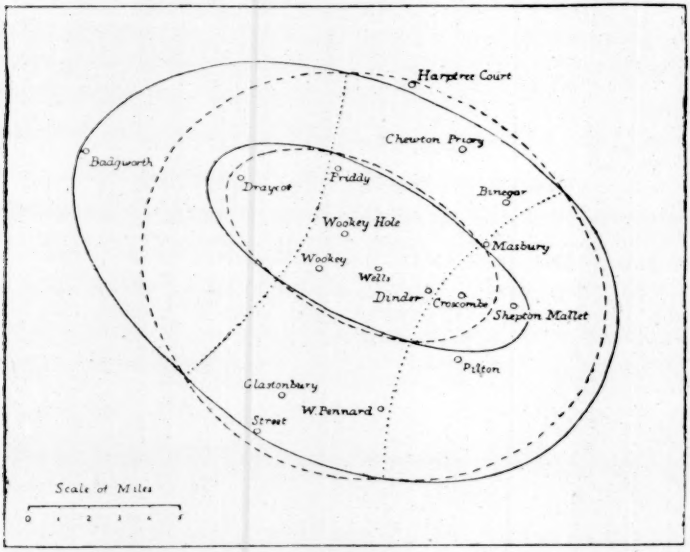


FIG. 1.—Somerset Earthquakes: Dec. 30–31, 1893.

So far as I can learn, the shock was in all parts a continuous series of vibrations, like that felt in an upper room when a heavy waggon or train passes. Its mean duration was 4 seconds.

The sound was compared by different observers to that of a waggon passing over loose stones, the dragging of a heavy weight or a heavy piece of furniture along the floor, a rolling peal of thunder, a stack of wood or coal tumbling down, the fall of an avalanche of snow, a terrific explosion, etc. As a rule, the beginning of the sound either preceded or coincided with that of the shock, while the end of the sound either coincided with or followed that of the shock.

Second Earthquake: Dec. 31, 12.28 *a.m.*—Of this earthquake, there are 41 records from 25 places, and negative records from 20 places, the latter being the same as for the first earthquake.

The intensity of the shock at Wells and one or two other places was about 5. The disturbed area is more elongated than the former. It is 19¾ miles long, 12½ miles broad, and contains 180 square miles. Its longer axis runs from W. 27° N. to E. 27° S.; and its centre is ¾ mile W. 6° S. of Wells.

The isoseismal 4 is $11\frac{1}{2}$ miles long, $4\frac{3}{4}$ miles broad, and includes 43 square miles; the direction of its longer axis being W. 30° N. and E. 30° S. Its centre is $\frac{3}{4}$ mile W. 27° N. of Wells, and $\frac{1}{4}$ mile from the corresponding centre for the first shock, the line joining the two centres being parallel to the longer axis of both curves. The distance between the isoseismals is nearly 3 miles on the north-east side, and nearly 5 miles on the south-west side.

In nature and duration the second shock resembled the first. It was again a continuous series of vibrations, like that felt in a house built directly over an underground railway, according to one observer. The mean recorded duration was slightly less than 4 seconds, but most of the observers were awakened by the shock and may have missed the earlier tremors.

The sound is also compared to similar types. Among them may be mentioned a goods train passing over an iron bridge, a deep peal of thunder, a rushing wind, the fall of boxes on a floor, and tremendously heavy blasting but prolonged.

In estimating the frequency of comparison to different types, the small number of descriptions renders it advisable to do so for the two shocks together, especially as there are several other accounts in which the particular shock is not distinguished. The sound is compared to passing waggons, etc., in 26 per cent. of the records, to thunder in 11 per cent., to wind in 5, loads of stones falling in 13, heavy bodies falling in 11, explosions in 26, and to miscellaneous sounds in 8 per cent. These are about the usual proportions for a slight earthquake, except for the rather frequent references to explosions. The exception is in reality only apparent, for, in all but three cases, the reference is to an explosion prolonged or else to an explosion in the midst of an undescribed rumbling sound; the three places are Wells, Wookey, and Wookey Hole, and these are close to the epicentre. Again, the comparison to passing waggons implies that the sound was of long duration and gradually increased to a maximum and then died away; but this is not the case with the dragging of heavy boxes along the floor, which I have included in the same type. Comparisons to the latter sound come from Priddy, Street, and West Pennard, places which are not far from the shorter axis of the disturbed areas. The general result is, as we should infer, that the sound is of long duration near the ends of the longer axis, and of short duration near the ends of the other.

Relation between the two Earthquakes.—The relation between the isoseismal lines of these two earthquakes is somewhat peculiar. They are almost concentric. Yet both isoseismals of the second shock overlap those of the first towards the east and west, and are overlapped by them towards the north and south. Moreover, though the second shock had the larger disturbed area yet its intensity was not everywhere the greater. The first shock is reported to have been the stronger at Binegar, Chewton Priory, Coxley, Dinder, Priddy, Street, West Pennard, Wookey, and Wookey Hole; and the second shock at Croscombe, Draycot, Masbury, Pilton, Shepton Mallet, and Wells. Now, at the points where the isoseismals

intersect, the intensities of both shocks were the same, and, if curves (represented by dotted lines on the map) be drawn through the four points of intersection on both the west and east sides of the disturbed areas, the intensities of both shocks at any point of these curves should be the same. These lines divide the whole area into three districts. In the central district lie all the places where the first shock was regarded as the stronger, and in the terminal districts those where the second was the stronger, with one exception, that of Wells. This city lies near the centres of both disturbed areas, and, according to a newspaper report, the second shock was severer than the first. Too much stress should not be laid upon this exception, for there is always some variation in the estimates of the relative intensities of two shocks where these do not differ greatly.

The explanation of the peculiarity is simple enough. The more elongated form of the isoseismal lines of the second shock implies that it had a longer focus. The overlapping towards the north and south of the second disturbed area by the first shows that the initial intensity of the first shock within a given area of the focus was greater than that of the second. Thus, the second earthquake owes its larger disturbed area simply to the greater length of its focus.

Third Earthquake: Dec. 31, *about* 4 *a.m.*—A slight shock was felt at Priddy, Street, Wells, and Wookey. At Street and Wells it was accompanied by sound. So far as we can judge from the distribution of these places it would seem that the epicentre lay to the west of the epicentres of the two first shocks.

Origin of the Earthquakes.—It has been suggested that the shocks were not of seismic origin, but were caused by the fall of large masses of rock in underground channels. If this were so, the disturbed areas and isoseismal lines would have been approximately circular and the sound would have been compared almost exclusively to explosions or the fall of heavy bodies. The elongated forms of the isoseismal lines and the general character of the sound are therefore conclusive against such an explanation.

On the other hand, all the phenomena known to me are in complete accordance with the view that the shocks were caused by slips along a fault, running W. 30° N. and E. 30° S., hading towards the south-west, and passing through a point between one and two miles north-east of Wells and between Wookey Hole and Priddy. The Geological Survey map contains no fault in this position, but it will be noticed that the direction assigned to the earthquake-fault is roughly parallel to that of the Mendip Hills in this district. The focus of the first shock must have been about 4 miles and that of the second about 6 or 7 miles in length.

Fort William Earthquake: Jan. 12, 1894.

Owing to its time of occurrence (about 11.50 or 11.55 p.m.) and to the small number of villages within the disturbed area, I have only been able to obtain 17 records from 14 places, in addition to negative records from 5 places. I regret my failure especially in

this case, as the earthquake appears to be unique in one respect among British earthquakes of the last eleven years.

So far as the accounts may be trusted, the disturbed area appears to consist of two detached portions—one in the neighbourhood of Fort William, the other in Moidart and Arisaig in the extreme west of Inverness-shire. Eleven of the places of observation lie in the former area and three in the latter, while between them there are three places (Kinlochiel, Duisky, and Kingairloch) at which, I am told, the earthquake was not observed. Much reliance should not of course be placed on so small a number of negative records, especially for an earthquake which occurred at midnight; but there is also distinct evidence that, in the eastern area, the shock was much weaker on the west than on the east side of Loch Linnhe.

In a country district, time-records are naturally liable to considerable error, but those in both parts of the disturbed area agree in giving the time as nearly midnight. If there were two separate impulses, there is therefore no evidence to tell us which occurred first.

Of the places in the eastern area, four (Ardgour, Banavie, Carpach, and Trislaig) are on the north-west side of or close to the great Highland fault, and the remaining seven (Achintore, Blarmacfoldach, Carnach, Fort William, Glencoe, Nether Lochaber Manse, and North Ballachulish) are on the south-east side. The boundary of the area cannot be determined satisfactorily from these places, but it is about 17 miles long, its longer axis is roughly parallel to the great fault, and it extends to a much greater distance on the south-east than on the north-west side of the fault. If the shock felt in the eastern area were due to a slip of the fault, or of one of the system of faults, it is clear that the fault concerned must hade to the south-east. This is also shown by the intensity of the shock; for the only places where it attained the degree 4 (Blarmacfoldach, Carnach, and Nether Lochaber) are on this side.

As a rule, the shock resembled the tremors felt in a house when a heavy conveyance is passing. At Nether Lochaber Manse, however, the movement was stronger and more distinct, being like that felt in a heavy carriage in rapid motion on a rough road, and culminating in a severe vibration. The sound was compared by three observers to the rumbling of a cart or a heavy loaded waggon on a rough road, and by three to distant thunder.

Very little can be ascertained with regard to the western part of the disturbed area. The shock was felt only at three places, namely, Arisaig, Glenmoidart, and Roshven; at the second of these places the intensity was 4. The sound was described by one observer as like distant thunder, and by another as like the explosion of a large quantity of gunpowder at a great distance. The observer at Glenmoidart informs me that a second and weaker shock was felt there in the daytime some days afterwards, and a third at night.

It seems to me probable from the above evidence that there were two distinct shocks, each disturbing a separate area; and that the shock felt in the neighbourhood of Fort William was due to a slip of

the great Highland fault. With regard to the origin of the other shock nothing can be ascertained, nor is there any evidence to show whether the proximity in time and place between the two shocks was other than accidental.

Glen Garry Earthquake : Jan. 25, 1894.

A shock, of intensity 4, was felt by Mr. M. Matheson and at least four other persons at Ardochy at 1.7 p.m. The vibration was like that produced by a carriage passing over a wooden bridge; it was followed by a distant roar.

Annandale Earthquakes : March 8 *and May* 14, 1894.

My only authorities for these two shocks are the accounts given in the local newspapers.[1] I was unsuccessful in my attempts to obtain further information, but houses are widely scattered in the district. I see no reason for doubting the seismic character of the shocks.

The first earthquake occurred about midday on March 8, and was most marked in the central district of Corrie.

The second occurred during the afternoon of May 14 in the upper valley of the Milk. It was distinctly felt at Corrie Bridge, Corrielaw, and Rosebank (about two miles east of Lockerbie), and possibly also in the district about Eskdalemuir. The intensity was at least 4 in the first three places mentioned. At Corrie Bridge, the shock was accompanied by a noise resembling the distant firing of cannon.

Comrie Earthquake : July 12, 1894.

A very distinct trembling (of intensity 3) was felt at about 11 p.m., and was accompanied by a dull rumbling sound lasting about 6 seconds. So far as I know, the earthquake was only observed at Comrie and Dalginross, which is about $\frac{1}{4}$ mile south-east of Comrie; and I have six negative records from places in the vicinity. The disturbed area must therefore have been very small, and the epicentre may be regarded as coincident with the village of Comrie.

Glen Garry Earthquake : Sept. 18, 1894.

Mr. Matheson informs me that this shock was not so strong at Ardochy as that felt on Jan. 25. It occurred at 10.10 a.m., and was followed by a loud noise. It was also felt on the opposite (or south) side of Loch Garry.

Fort William Earth-Sound : Jan. 9, 1895.

The occurrence of this earth-sound was noticed in the daily papers, but for the details given below I am indebted to Mr. Angus Rankin of the Ben Nevis Observatory.

The noise was heard between 5.45 and 5.50 a.m. by many persons, some lying awake in bed, others preparing to go to work; but it was not loud enough to waken sleepers. It is described by all as a rumbling noise resembling distant thunder, and to one observer at Fort William it appeared to travel in a north-easterly direction. No

[1] *Annandale Herald* (Lockerbie), May 17; *Dumfries and Galloway Courier and Herald* (Dumfries), May 19; and *Eskdale and Liddesdale Advertiser* (Langholm), May 23.

shock or tremulous motion was felt by anyone, and the seismograph at the Low-level Observatory at Fort William showed no sign of any movement. The noise was heard also at Blarmacfoldach and Lundavra, which are respectively 3 and 5 miles to the south of Fort William; all three places being close to the northern boundary fault of the Highland district. As to the seismic origin of the sound, there can be little doubt, for the district is one where slight shocks are occasionally felt, and all the observers agree that it was an 'earthquake-noise.' So far as our knowledge of the earth-sound goes, its evidence confirms the conclusion that the great fault, or one of the system of faults, hades to the south-east.

(*To be continued in our next Number.*)

IV.—Report on the Drift at Moel Tryfaen.[1] Drawn up by the Secretary, E. Greenly, F.G.S.

Introduction.—In August, 1898, it became known that what is perhaps the clearest and most instructive section in the famous high-level drift deposits at Moel Tryfaen must in a short time be swept away in the course of the quarrying operations. There are two slate quarries on Moel Tryfaen, the "Alexandra" and the "Moel Tryfaen" Quarries, excavated in the same line of strike of the slates. Gradually expanding, they had approached each other so nearly as to leave a narrow bank between them with no more than a yard or two of uncut turf upon it. Now the drift sections

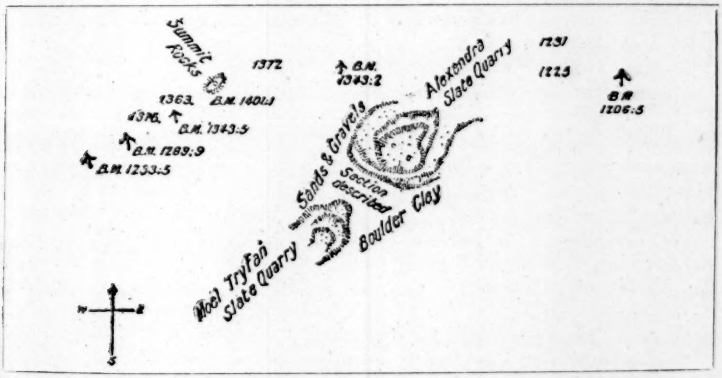


Fig. 1.—Map of part of Moel Tryfaen from Six-inch Ordnance Map.

thus in danger of destruction are exceedingly important for the following reasons: (1) They are at right angles to the strike of the slates, and thus display the character of the underlying rock

[1] Report of the Committee, consisting of Dr. H. Hicks (Chairman), deceased, Mr. E. Greenly (Secretary), Professor J. F. Blake, Professor P. Kendall, Mr. G. W. Lamplugh, Mr. J. Lomas, Mr. T. Mellard Reade, Mr. W. Shone, and Mr. A. Strahan, appointed to make photographic and other records of the disappearing drift section at Moel Tryfaen (spelt Tryfan in New Ordnance Survey Maps). Reprinted from the British Association Report, 1899 (1900), pp. 414–423.

surface; (2) they show the nature and position of the junction of the shelly sands and gravels with the overlying Boulder-clay; (3) the false bedding and other structures in the sands and gravels are best seen along them; (4) they have been more accessible than the other sections in the quarries. A Committee was therefore appointed to preserve, by photography, supplemented by a written report, an impartial record of the phenomena displayed in these sections. The Committee have much pleasure in acknowledging their obligations to Mr. Menzies, the manager of the Alexandra Quarry, who, with a large-minded appreciation of scientific work for which geologists cannot be too grateful, offered to suspend operations in that part of the quarry for three months, besides showing the Committee every hospitality and facilitating their work by all means in his power.

Photographs.—Six whole-plate and five half-plate photographs were taken by Mr. John Wickens, F.R.P.S., photographer, of Bangor.

The views taken are:—

1. General view of section from W.N.W. end.
2. General view of section from E.S.E. end.
3. General view from W.N.W. of Moel Tryfaen Quarry, including neighbourhood.
4. Boulder-clay by engine-house at E.S.E. end section.
5. Sands seen below Boulder-clay.
6. Junction, wedge of Boulder-clay in sand and gravel.
7. Base of sands and terminal curvature near W.N.W. end of section looking S.S.W.
8. Duplicate, showing a little more of slate.
9. Similar phenomena on N.E. side of quarry (third gallery) looking N.N.E.
10. Duplicate, a little nearer.
11. Rocks on summit of hill from N.W.

Description of Section.—The Chairman, the late Dr. Hicks, F.R.S., visited the section on September 26, 1898; and on November 5, 1898, Messrs. Kendall, Lamplugh, Lomas, Mellard Reade, Shone, and the Secretary examined it and recorded the facts embodied in this report. On July 1, 1899, the Secretary added items 1, 2, and 9.

As there have been serious differences of opinion as to the interpretation of the Moel Tryfaen phenomena, the Committee wish to emphasize the statement that this report is intended to be a record of observed facts only, without reference to any conclusions that may be drawn from these facts.

The observations are here arranged under thirteen heads. All the details were examined from the side of the Alexandra Quarry, which was the better and more accessible section of the two.

1. *Bearing and Distance of Section from Hilltop.*—About 800 feet E.S.E. to the middle of the section.

2. *Length of Section.*—From 700 to 750 feet.

3. *Direction of Section.*—The sections are in curves concave to N.N.E. and S.S.W. in the "Alexandra" and "Moel Tryfaen" Quarries respectively, so that a tangent to both curves at their nearest point, about the middle of each section, is about W.N.W.–E.S.E.

4. *Height of Rock Surface.*—The floor of Gallery "No. 1," the highest in the Alexandra Quarry, is at 1,281 feet above sea-level. The surface of the rock emerges from below drift in the floor of this gallery a few yards E.S.E. of the edge of the Boulder-clay, and rises gradually to W.N.W. The angle measured by Abney Level from the opposite side of the Alexandra Quarry is from 2°·5 to 6°·0 (average 4°·25) to E.S.E. (Photographs 1, 2, 3). But the surface undulates (Photographs 7, 8).

5. *Slope of Surface of Drift along Section* (Photograph 3).

6. *Strike and Dip of Cleavage of Slates.*—N. 30 E., 95°–98° to S. of E. *Dip of Bedding of Slates.*—25°–30° S.S.E. or S., but undulating.

7. *Thickness of Drifts along Section.*—25 feet maximum, thinning toward hilltop (Photographs 1, 2, 3, 4, 11). The sections which will remain at present will show the varying thicknesses in the quarries.

8. *General Nature of the Drifts.*—Their general characters have been often described. Towards the N.W. are sands, sandy loam, and gravel, with shells, Boulder-clay coming on above them towards the S.E. (Photographs 1, 2, 3).

9. *Position of Boundary of Sandy Group and Boulder-clay.*—The junction at the surface between the quarries is about 1,000 feet from the hilltop.

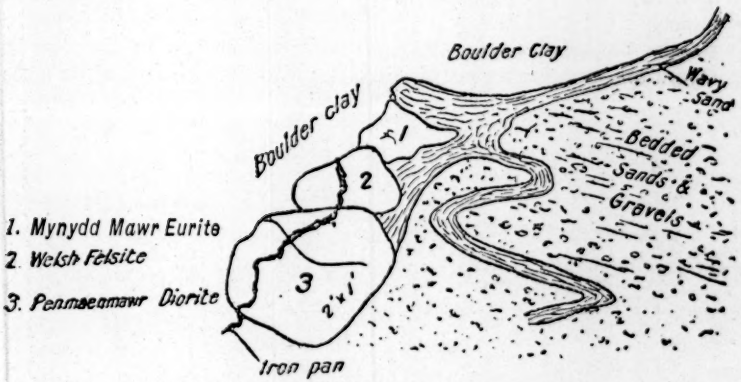


Fig. 2.—Contortions in Sands below Boulder-clay.
(Section at x in Fig. 3 on Elevation.)

10. *Character of the Sandy Group.*—The beds may be described as sand and yellow loam with gravelly streaks and pockets containing shells. The shell fragments were found on November 5 only in the gravel, none but the finest crumbs having been seen in the sand and loam (*a*, p. 120). The bedding is very irregular, and even here and there curved (Photograph 1), but contortion has only been observed near the junction with the overlying Boulder-clay (*β*, p. 120).

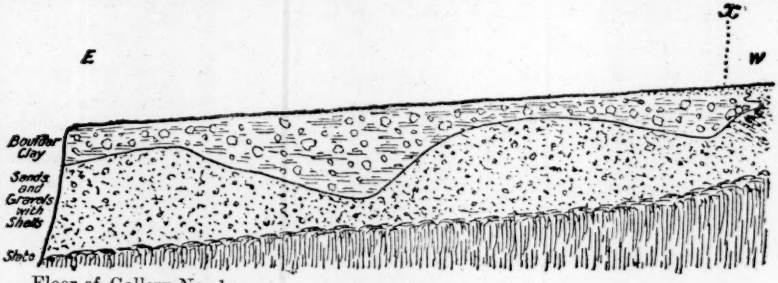
11. *Characters of the Boulder-clay.*—This is a good typical, tough, strong, unstratified till, such as is mostly found in mountain

districts, dark grey in colour and full of stones (Photograph 4). The stones are for the most part of moderate size, but some up to $3\frac{1}{2}$ and 3 feet (the visible part) occur. They are subangular and well striated. There seems to be a general slight upward inclination of the longer axes of the stones to E.S.E. or E. The longer axis of the large boulder mentioned pointed W. 20 S. — E. 20 N., and its eastern end was a little lifted. Nearly all the stones observed were of North Welsh origin, the riebeckite eurite of Mynydd Mawr being very abundant, but one pebble of a granite foreign to North Wales was obtained on November 5 (γ, p. 120). Extensive sections will remain, in which all points not depending upon orientation can be observed.

12. *Nature of Junction of Sandy Group and Boulder-clay* (Photographs 5, 6).—In a general way the sandy group passes under the Boulder-clay to the E.S.E., as described by previous writers. The sandy beds in places dip W. at the junction, and are also contorted, a string of loamy sand two inches thick being bent into sharp folds (Fig. 2). These contortions,[1] however, were not very clearly displayed on November 5 on account of slipping.

The Boulder-clay rests upon an uneven surface of the sandy beds, as shown in the annexed section (Fig. 3), which was measured, and is drawn to scale.

The photograph No. 5 is taken close to the E.S.E. end of this section. The Boulder-clay is "good typical stony till," and the underlying beds the usual sand and yellow loam with gravelly streaks and pockets containing shell fragments. In the lowest layers are angular fragments of slate, below which is broken slate



Floor of Gallery No. 1.

FIG. 3.—Junction of Boulder-clay and Sandy Beds.
(Scale 1 inch = 36 feet; length of section 144 ft. 6 in.)

mixed with a small quantity of clayey matter resting on slate with terminal curvature.

Evidence has been adduced by previous writers to show that the sandy group overlies as well as underlies the Boulder-clay, so that the two groups interdigitate. The section as seen on November 5 could not be said to be conclusive on this point; but it is shown

[1] Very well seen on September 26.—H. H.

in Photograph No. 6, of which Fig. 4 is an explanatory diagram: (*a*) is very stony Boulder-clay, stones mainly of Welsh origin; (*b*) yellow loam and sand bedded and contorted; (*c*) bedded sand and gravel, 1 foot to 2 feet; (*d*) soil 6 inches. The lower edge of the Boulder-clay dips downward into the exposed face rather steeply. BBB are boulders with angular ends projecting from the clay into the sand, the largest being apparently of Penmaenmawr diorite, and the other two of riebeckite eurite of Mynydd Mawr. There is no distinct evidence that the shelly sand and gravel anywhere overlie the Boulder-clay. A close examination showed a distinct line, probably of erosion, between that which passes above and that which passes beneath the Boulder-clay, in which last only were shell fragments found. The sand and gravel above the Boulder-clay may be altogether newer than that in the lower part of the section containing the marine shells, and may possibly be merely hill-wash.

13. *Base of the Drifts and Nature of Underlying Rock Surface* (Photographs 7, 8).—The surface of the slate is seen in contact with the sandy group only, the Boulder-clay not reposing directly upon the rock in any part of the section. The surface of the slates is exceedingly shattered, the shattering affecting them to the depth of a foot or two. The shattered edges are, with (*δ*, p. 120) certain local exceptions, bent over in an E.S.E. direction, i.e. to the left of an observer looking along the strike of the cleavage to the S.S.W., the displaced laminæ retaining generally their original direction of strike. The displacement usually goes down to the first horizontal joint below the surface, and is a 'displacement' rather than a true curvature.

These terminally disturbed slates pass up into a band of slate breccia or rubble, composed of angular fragments (*ε*, p. 120). This forms a well-marked band all along the section, and is from

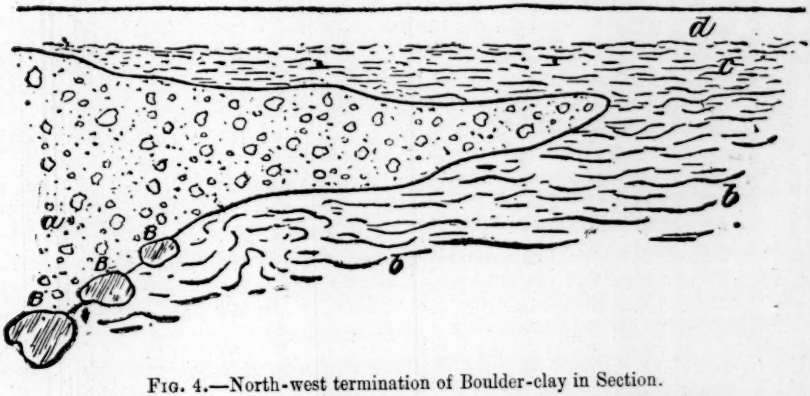


Fig. 4.—North-west termination of Boulder-clay in Section.

1 to 3 feet thick. The fragments become smaller towards the top, and have at first a slight inclination upwards to the E.S.E., the upper layers, however, becoming horizontal. Where not obscured

by slipping, the junction with the sandy drift above is usually well marked, but angular and subangular débris is mixed with the lowest layers of the gravel.

Conclusion.—The above description is not intended to be exhaustive, though the description of the section about to be destroyed has been made as full as seemed possible at the time. Incidentally certain details in other parts of the quarries were observed, and have therefore been included; but these form only a subsidiary and unessential portion of the report, and are therefore placed in a separate appendix,[1] because the sections in which they are displayed are in no danger of destruction. Generally, moreover, it will be observed that the report is confined to questions of structure, physical relations, and measurements; and that many matters of the highest importance, such as species, distribution, and state of preservation of the shells, the nature of the boulders in the sands and the clay, the character of the fine material of the drifts, are not dealt with. These are points which can be investigated as well as ever in extensive sections, which the quarrying will keep clear and open.

It must not be supposed that the Moel Tryfaen sections are being destroyed as a whole. It is the part specified only that is perishing; and the drifts of the quarries will continue to furnish ample scope for research into many matters of great importance to glacial geology for many years to come.

Note A.—*By Chairman and Members.*

(α) § 10.—Some of the best preserved specimens sent to me by Mr. Menzies from the drift in the Alexandra Quarry have adhering to them a fine loamy sand, and it is in such a material, interstratified with sand and gravels, that I have usually obtained the best specimens of shells in the Welsh sections.—H. H.

(β) § 10.—In addition to boulders of North Welsh rocks, they are full of far-travelled erratics from the Lake District and the South of Scotland.

(γ) § 11.—This deposit, therefore, differs widely in regard to its included stones from the underlying sandy group, which contains many far-travelled erratics, as before stated; as it does also in the apparent absence of marine shells and of Foraminifera.

(δ) § 13.—P. F. Kendall and J. Lomas would prefer to say that the general direction of displacement had only a few individual exceptions, which might indeed be due to quarrying operations.

(ϵ) § 13.—This material was not observed by the Committee to contain any glacially striated fragments or any foreign stones—no fragments, indeed, but of the underlying slates.

Note B.—*By T. Mellard Reade, F.G.S.*

Specimens of the drift were taken by me at the meeting on November 5, 1898, in the positions shown on the following sections

[1] See Appendix C.

(Figs. 5 and 6), and submitted to Mr. Joseph Wright, F.G.S., of Belfast.

He very kindly examined them for Foraminifera, and in all discovered twenty-three species. The results seem to show that the Foraminifera occur in the most abundance in the shelly sand. None were found in the overlying Boulder-clay (Specimen 4), and a few only in Specimens Nos. 1 and 2. In No. 3 the Foraminifera were more plentiful and of species common to the low-level Boulder-clay of Lancashire, Cheshire, and the Vale of Clwyd. As usual, *Nonionina depressula* was common, and far outnumbered the other species.

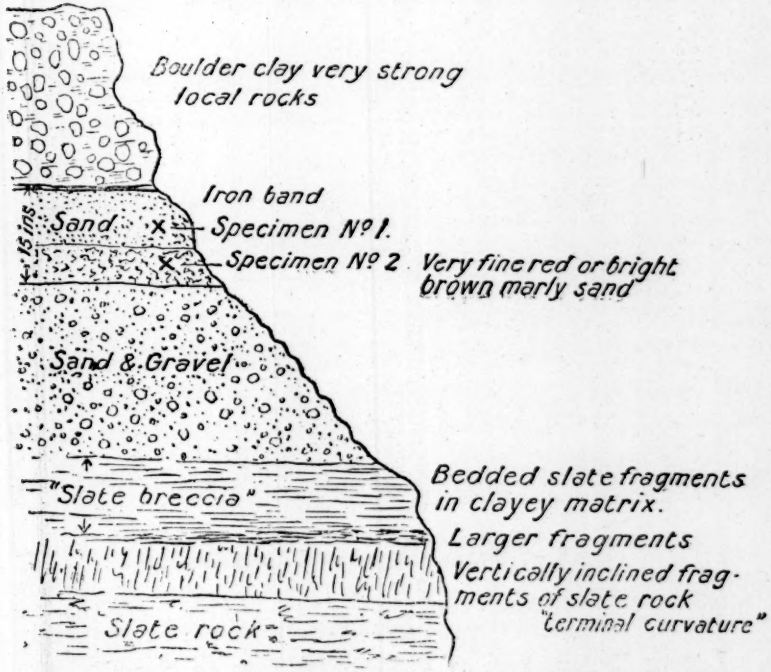


FIG. 5.—Section showing position of Foraminiferal beds.

The high-level drift generally does not appear to have been searched much for Foraminifera. The only other published list from Moel Tryfaen that I can find is that given by Miss Mary K. Andrews.[1]

This list was also the result of Mr. Wright's examination of specimens collected by Miss Andrews. In all twelve species are

[1] Annual Report, Belfast Naturalists' Field Club, 1894–95, pp. 209, 210.

enumerated, those common to this list being marked with an asterisk, and being eight in number.

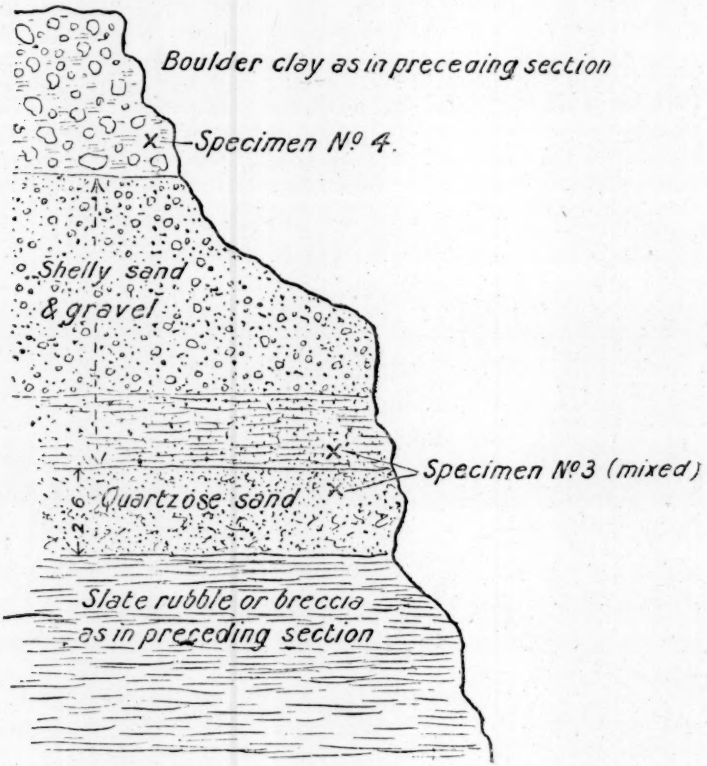

Boulder clay as in preceding section
Specimen No 4.
Shelly sand & gravel
Specimen No 3 (mixed)
Quartzose sand
Slate rubble or breccia as in preceding section

FIG. 6.—Section showing position of Foraminiferal beds.

NOTE C.

LIST OF FORAMINIFERA OF PLEISTOCENE BEDS OF MOEL TRYFAEN.

By Joseph Wright, F.G.S.

No. 1.—Weight of sand, 1 lb. 1·7 oz. troy. After washing, fine 10·8 oz.; coarse 1·5 oz. In this sample, as well as in all the others which I examined, the greater portion of the stones were more or less rounded, the others being angular.

Lagena semistriata (Will.). Very rare.
**Nonionina depressula* (W. & J.). Very rare.

No. 2.—Weight of sand, 1 lb. 2·7 oz. troy. After washing, fine 7·3 oz.; coarse 2·2 oz. Very fine bright brown sand.

Lagena lineata (Will.). Very rare.

No. 3.—Weight of sand, 2 lb. 3·5 oz. troy. After washing, fine 1 lb. 8·2 oz.; coarse 5·4 oz. Fragments of shells.

Miliolina seminulum (Linn.). Rare.
Bulimina pupoides (D'Orb.). Very rare.
Bolivina punctata (D'Orb.). Frequent.
* ,, *plicata* (D'Orb.). Common.
**Cassidulina crassa* (D'Orb.). Common.
Lagena sulcata (W. & J.). Very rare.
,, *Williamsoni* (Alcock). Very rare.
,, *semilineata* (Wright). Very rare.
* ,, *squamosa* (Montg.). Very rare.
,, *marginata* (W. & B.). Rare.
,, *quadrata* (Will.). Very rare.
,, *clathrata* (Br.). Very rare.
,, *Orbignyana* (Seg.). Very rare.
,, *quadricostulata* (Rss.). Rare.
Uvigerina angulina (Will.). Very rare.
Globigerina bulloides (D'Orb.). Very common.
Orbulina universa (D'Orb.). Frequent, very small.
**Discorbina rosacea* (D'Orb.). Very rare.
,, *Wrightii* (Br.). Common.
**Pulvinulina Karsteni* (Rss.). Rare.
**Nonionina depressula* (W. & J.). Most abundant.
**Polystomella striato-punctata* (F. & M.). Very rare.

203 specimens of *Nonionina depressula* were obtained from this gathering, whilst the other twenty-one species numbered only 102.

No. 4.—Weight of sand, 2 lb. 6·7 oz. troy. After washing, fine 6·6 oz.; coarse 1·3 oz. Sand very dirty, and having a large proportion of stones in it.

No Foraminifera.

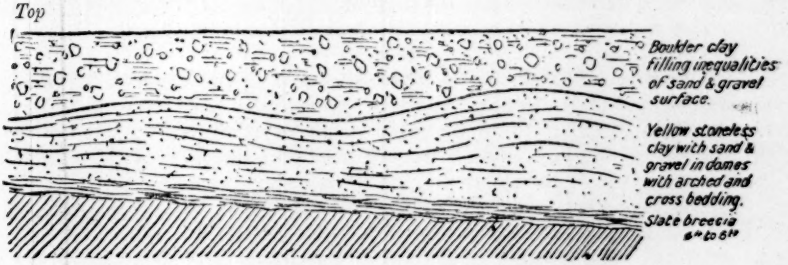

Top
Boulder clay filling inequalities of sand & gravel surface.
Yellow stoneless clay with sand & gravel in domes with arched and cross bedding.
Slate breccia

FIG. 7.—Diagram at north-east side of Alexandra Quarry, showing dome-like arrangement of sand and gravel beneath Boulder-clay.
(Length 50 to 60 yards; height about 60 feet.)

NOTE.—Much of the middle series consists of fine plastic reddish-yellow clay or silt without stones, the kind of material common in the stratified drifts of the Isle of Man. Shell fragments rather plentiful in the gravelly streaks, but none seen in the clay or sand.

P.S.—For the sake of those interested in the drifts of Moel Tryfaen, it may be mentioned that copies of the photographs alluded to in this Report may be seen in the collection belonging to the British Association (at Jermyn Street Library); and of the more important of them also at the Museums of Science and Art in Edinburgh and Dublin. Copies have also been sent to Chicago and Ottawa.—E. G.

REVIEWS.

I.—An Estimate of the Geological Age of the Earth. By J. Joly, M.A., B.A.I., D.Sc., F.R.S., F.G.S., M.R.I.A., Hon. Sec. Roy. Dublin Soc., Professor of Geology and Mineralogy in the University of Dublin. Scientific Transactions of the Royal Dublin Society, ser. II, vol. vii (1899); 4to, pp. 44.

THE paper consists of an introduction and these nine sections :—

I. The estimate of geological time.
II. The original condition of the ocean.
III. The supply of sodium by the rivers.
IV. The saline deposits.
V. The alkalies of the rocks.
VI. The potash of the rivers.
VII. Uniformity of denudation by solution.
VIII. The alkalies of sediments, and the geological age of the latter.
IX. The solvent denudation of the ocean.

And two appendices.

Appendix 1 is generally useful. It contains a list of numerical quantities adopted in the calculations. Appendix 2 is a list of sources of error which may modify the conclusions.

The matters treated of in the nine sections are epitomized in the introduction.

The first point argued is, that so much of the removal of the land surface as is due to solution may be accepted as a uniformitarian process; and this being granted, if we take the one element of sodium, which is dissolved out of the rocks and enters the ocean through river discharge, and if we assume that there was no sodium in the primæval ocean, the amount of sodium in the ocean divided by the amount annually brought down by rivers will give the length of time during which the accumulation has been going on, and will be a measure of the age of the world.

Professor Joly claims that the amount of sodium in the ocean agrees very well with that which must have been lost by the crystalline rocks in the process of their being converted into the existing volume, as usually estimated, of the sedimentaries. This would decidedly support his view that the sodium of the ocean has been derived from the crystalline rocks, and that the primitive ocean was devoid of that element.

I. The data upon which the calculations are made are as follows: "The absolute masses of the ingredients of the ocean" are :

	Tons.
Sodium chloride	$35{,}990 \times 10^{12}$.
Magnesium chloride	$5{,}034 \times 10^{12}$.
Magnesium sulphate	$2{,}192 \times 10^{12}$.
Lime sulphate	$1{,}666 \times 10^{12}$.
Potassium sulphate	$1{,}141 \times 10^{12}$.
Magnesium bromide	100×10^{12}.
Lime bicarbonate	160×10^{12}.

"Of the sodium chloride 39·32 per cent. is sodium. In the sea, there is therefore a mass of sodium amounting to $14{,}151 \times 10^{12}$ tons."

The materials in tons per cubic mile of nineteen of the principal rivers of the world (after Sir J. Murray) are next given, and from these it is calculated that they contain 24,106 tons of sodium per cubic mile. "The total volume [of water] discharged by the rivers *into the ocean* is 6,524 cubic miles per annum."

The mass of sodium in the ocean divided by the mass annually brought down by the rivers gives the length of time in which, at the present rate, the mass in the ocean can have accumulated. The result is 89,565,000 years. But Professor Joly prefers to use a later estimate of the volume of the ocean, which would lengthen the "period of geological denudation to 94,800,000 years nearly."

The foregoing gives the pith of Professor Joly's very ingenious theory of the age of the earth. The remaining sections are subsidiary to it, and are apparently intended to meet possible objections, and to render the first estimate more accurate.

II. "On the Original Condition of the Ocean." This is a necessary inquiry; for unless it can be premised that there was no sodium in it, the argument clearly fails, and the earth's age will be proportionately shorter by an unknown amount. The author assumes that the earth was once molten, and considers that, upon cooling, "the upper part of what is now the earth's crust must have contained as silicates, in the form of slag, lava, or rock, the alkaline earths now appearing chiefly as carbonates, the alkalies now distributed between the salts of the sea and the alkali silicates of the rocks, along with iron and alumina. The early hydrosphere must for want of other known alternative be supposed to have contained a quantity of hydrochloric acid, roughly represented by the chlorine now in the ocean."

We next find speculations as to the sequence of events preceding and following the first condensation of water on the surface; and it is considered improbable that a uniform ocean ever covered the entire globe; and the author inclines to the opinion that the sub-oceanic crust is more dense than the continental, and that ocean basins have been permanent. This part of the essay is of much interest, but does not very closely concern the main question of the age of the earth.

We have here quoted an important analysis by Mr. F. W. Clarke (Bull. U.S.A. Geol. Surv., 1897), "which may fairly represent the composition of the older crust of the earth."

"SiO_2	59·77	Na_2O	3·61
Al_2O_3	15·38	H_2O	1·51
Fe_2O_3	2·65	TiO_2	0·53
FeO	3·44	P_2O_5	0·21
CaO	4·81		
MgO	4·40		99·14
K_2O	2·83		

"Such a rock, or lava, attacked by a heated solution of hydrochloric acid, must ultimately yield its iron, calcium, magnesium,

potash, and soda as chlorides. The atomic percentages of Clarke's average are given by himself as follows:—

Iron	4·71	... ...	take up	9·0
Calcium ...	3·53	... ...	units of	6·3
Magnesium ...	2·64	... ...	chlorine	7·6
Potassium ...	2·35	... ...		2·14
Sodium ...	2·68 "	... ...		4·1

Having given the composition of the crust, the author next considers how the chlorine of the heated hydrochloric acid, which he supposes then to have been in the ocean, would have been distributed among the bases.

It is evident that any sodium which was obtained by rock solution from the floor of the primæval ocean must be deducted from that supplied by the rivers, otherwise the age of the world will be reckoned too long. Professor Joly proposes to estimate the former by considering the chlorine in the ocean. Of whatever chlorine there was in the primitive ocean the sodium would take 14 per cent. (reckoning from the proportion of sodium to the other bases in the crust). But some chlorine is also supplied by the rivers, and by rain upon the land. He allows for this at a guess 10 per cent. Deducting this, the total supply by rivers is $97{\cdot}8 \times 10^6$ tons of sodium chloride per annum. There are other chlorides (lithium 16×10^6, ammonium $6{\cdot}5 \times 10^6$) in the rivers. Thus we find 76×10^6 tons of chlorine discharged into the ocean annually by rivers.

"If we assume that the final result as to the duration of denudation will not be far from 86×10^6 years, we arrive at a total deduction of $6{,}536 \times 10^{12}$ tons [of chlorine] as a correction on the amount of chlorine contained [at present] in the sodium chloride of the ocean." This, however, seems to *postulate* the period of 86×10^6 years, which is the thing to be found. The calculation will be—

	Tons.
Chlorine in the sod. chl. now in the ocean	$24{,}155 \times 10^{12}$
Chlorine in the mag. chl. now in the ocean	$4{,}161 \times 10^{12}$
	$28{,}316 \times 10^{12}$
Deduct chlorine introduced by rivers in 86×10^6 years ...	$6{,}536 \times 10^{12}$
	$21{,}780 \times 10^{12}$

"The result is $21{,}780 \times 10^{12}$ tons" of chlorine in the original ocean. Of this, 14 per cent. will have been combined with sodium as already explained, the remainder combining with the other bases of the magma. This gives $1{,}972 \times 10^{12}$ tons of sodium in the original ocean. Hence we have—

Tons of sodium in the present ocean	$15{,}627 \times 10^{12}$
Tons of sodium in the original ocean...	$1{,}972 \times 10^{12}$
Difference given as brought in by rivers	$13{,}655 \times 10^{12}$

This, divided by the annual supply of sodium by rivers, viz. $15{,}724 \times 10^4$ tons, gives as a final result $86{\cdot}8 \times 10^6$ years for the age of the world.

III. In this section some slight modifications of the supply of

sodium by rivers to the ocean are considered. The estimate of 89·3 millions of years is finally arrived at as "based on the most complete estimates of probabilities."

IV. We next have a short geological discussion on the origin of beds of rock salt; but the author concludes that these have scarcely any bearing upon his theory.

V. In this section the rates of percentages of soda and potash in igneous and sedimentary rocks respectively are considered. Seeing that the sedimentaries have been ultimately derived from the igneous, the difference needs to be accounted for. The difference is considerable; for while in the igneous the percentages are of potash 2·83 and of soda 3·61, in the sedimentaries they are of potash 2·49 and of soda 1·47. "If now the inference is right that the missing alkalies [i.e. the deficiency of soda in the sedimentaries] were supplied to the ocean, we should expect to find, on a rough approximation of the bulk of sedimentaries, and hence of the original rocks giving rise to them, that such a mass of parent rock would be adequate to supply the sodium in the ocean." This the author claims to be the case, allowing for the sodium retained in beds of rock salt. The weight of this argument clearly depends upon what reliance we can place upon the estimate of the bulk of the sedimentaries, which is taken from Mr. Mellard Reade.[1] Professor Joly accepts his estimate of a layer 2 miles thick over the land area, which on deducting the calcareous rocks is reduced to 1·6 miles. This, however, is reduced still further by a course of somewhat complicated reasoning to 1·1 miles, and the conclusion, accentuated by italics, is thus stated:—

"*Hence it appears that, if a thickness of* 1·1 *mile of rock spread over the land area represent the bulk of the entire detrital siliceous sedimentary rocks, inclusive of submarine detritus, and this constitutes* 67 *per cent. of the entire sedimentaries of the earth, including matter in solution in the sea, the sodium contained in the sea, added to what is left over in the detrital sediments, would suffice to restore to the entire mass a soda percentage almost equal to that in the eruptive, igneous, and crystalline rocks*; the deficiency, about 0·4 per cent., exists partly in rock-salt deposits."

The bearing of this section upon the general argument is, that the sodium in the ocean may be regarded as having been all of it derived from the original rock magma.

VI. The ratio of potash to soda in the ocean is 1 to 31 nearly, whereas in the river discharge it is 1 to 2·8, that is, there is about eleven times as much potash compared to soda in the rivers as there is in the ocean. It is therefore clear that at this rate the present ratio of these alkalies in the ocean could not have been contributed by the rivers. "We must then suppose that the rivers are now supplying more potash relatively to soda than formerly; *or* that some process of abstraction of the potash from the ocean is in continual progress." The author comes to the conclusion that there is no reason to suppose that the ratio of the alkalies in the river supply differed in

[1] Geol. Mag., Dec. III, Vol. X (1893), p. 97.

times past from what it is now, but attributes the deficiency of potash in the ocean to a continual abstraction of that alkali in deposits which have always been, and still are, going on upon the sea bottom, especially in the form of glauconite. Moreover, while the soda brought by rain from the ocean is returned to it again, much of the potash is retained by vegetation, and finally deposited in the strata.

[Is it certain, however, that the primæval ocean did not contain soda? If it did, the excess would be at once explained.]

VII. The uniformity of denudation by solution throughout geological time is a first requisite of Professor Joly's calculation. The objection which would be probably made is, that the sodium supply by rivers will have been greater in early times. To meet this he first argues for a nearly equable distribution of land and sea all along, so that there would not have been formerly much larger areas exposed to denuding agency than now. This portion of the present section is very interesting from a geological point of view, and is well reasoned. No claim is made to settle definitely the ratios of rainfall during successive epochs.

In the next place the author meets the possible objection, that it might be thought that formerly greater areas of the land surfaces were occupied by crystalline rocks, which, containing a larger percentage of sodium than the sedimentaries, would have supplied that element at a quicker rate. In later times the sedimentaries would occupy a larger proportion of the exposed surface, but the balance of supply would, he thinks, be rectified by the greater ease with which the sedimentaries, aided by disintegration into soils, yield up the alkalies they contain.

VIII. In this section "a very interesting but difficult line of enquiry is suggested in the probable facts of geological denudation" referred to in the previous section. The object in view appears to be to support the theory of uniformity of sodium supply.

IX. By "the solvent denudation of the ocean" is meant its action upon the coastlines. This is believed by the author to be small compared with what goes on upon land surfaces. Moreover, experiment has shown that sea-water has little effect in decomposing felspars, and similarly the volcanic products which are so abundant in deep-sea deposits have the alkali ratio of igneous, not of sedimentary rocks—"a plain proof that the waters of the ocean do not affect them as would terrestrial rain and rivers." The correction on the world's age on account of the solvent denudation of the ocean will be sufficient if half a million years is allowed. The final conclusion is that "*our present knowledge of solvent-denudation of the earth's surface points to a period of between eighty and ninety millions of years having elapsed since water condensed upon the earth,* and rain and rivers and the actions continually progressing in the soils began to supply the ocean with materials dissolved from the rocks."

As Major Dutton has somewhere remarked, "If we enquire of Mother Earth her age her face is the face of a sphinx." Has

Professor Joly read her riddle aright? The suggestion of some criticisms may be excused.

In the first place, it does not appear safe to take the intensities of actions now going on as a measure of those in past ages, because the earth has been losing energy; and, as Professor Darwin has pointed out in his book on "The Tides," meteorological agencies must have formerly been more powerful than they are now. In the writer's opinion, in dealing with events of long past ages the interaction of the moon upon the earth ought not to be lost sight of. This is inversely proportional to the cube of her distance, which distance was once much less than it is now, if, indeed, the moon was not once a portion of the earth suddenly detached. If such was the case, the primæval condition of the earth's surface may have been profoundly modified by the stupendous event.

The assumption made that the primitive ocean did not contain alkalies appears to require that the alumina in the original magma was exactly proportioned to the alkalies, so that when the felspathic minerals were formed there was neither alumina left nor alkalies, as there certainly was silica in abundance, still uncombined. If this proportion did not hold, there would have been either alumina uncombined in the crystalline rocks, or alkalies over to combine with the acids in the ocean—presumably the latter, seeing that alkaline salts abound in it at present. That this due proportion should have existed does not seem probable. If there was soda in the primæval ocean, that would shorten Professor Joly's estimate of the earth's age.

The various sodium salts in the rivers are in the proportion of sulphate 32, nitrate 27, chloride 17, nearly. The decomposition of iron sulphide would supply the sulphuric acid. Bacteria in the soils would supply the nitric. But whence came the chlorine? The amount of 0·01 per cent. stated to occur in crystalline rocks seems insufficient. Sodium occurs as carbonate rather abundantly in some rivers and artesian wells, which, Sterry Hunt remarks, "has its source in the decomposition of felspathic minerals."[1] This shows that the direct product of these rocks is the carbonate rather than the chloride. Is it not probable that the chlorides of sodium, and to a small extent of lithium, are derived from sedimentary rather than from crystalline rocks; not from the decomposition of these rocks, but from what Sterry Hunt calls the "fossil sea water still to be found imprisoned in the pores of the older stratified rocks,"[2] and presumably in the younger as well?

This idea had occurred to the writer before referring to Sterry Hunt's book, and he had already begun to examine a specimen of the Silurian rock (Wenlock shale) obtained from the depth of 880 feet in the New River Company's borehole at Ware; for it seemed probable that this rock has never yet been exposed to atmospheric influences, so that it would contain all the salts which were present in the mud of the very early ocean from which it was

[1] "Chemical and Geological Essays," p. 85.

[2] Ibid., p. 41.

consolidated. And it is distinctly salt to the taste. On submitting a fragment of this rock for examination to Mr. Purvis, of the Cambridge University chemical laboratory, he found that it contained 0·568 of soluble matter, of which 0·042 per cent. consisted of chlorine calculated to sodium chloride. Now the specific gravity of this rock is 2·59. Consequently, since a cubic foot of water weighs 1,000 ounces, there are 1·08 ounces of chlorides in a cubic foot of the rock and 2·27 ounces of other soluble salts. In like manner a piece of Devonian shale from Meux Brewery in Tottenham Court Road at the depth of 1,070 feet was found to yield 1·11 per cent. soluble in water, but the amount of chlorine was too small to determine.

It is interesting to compare these old rocks with such as we might suppose would now be forming. Accordingly it was found upon squeezing dry some mud from Southampton Water that the matter soluble in water was 0·495 per cent., and of "chlorine calculated to sodium chloride 0·074 per cent." This mud was derived from Middle Bracklesham sands, and yielded a soft sandstone rock when consolidated in a hydraulic press.

Some mud from the Fleet near Weymouth, when treated in the same manner, yielded 0·9 per cent. of soluble matter, of which chlorine calculated to sodium chloride gave 0·29 per cent.

It is remarkable that the total amount soluble in these hypothetical recent rocks is closely analogous to that in the ancient rocks examined, and also that the proportion of sodium chloride in both cases is comparatively small; whereas in sea-water it is very much greater than that of any other salt. Mr. Purvis adds: "This pressed mud also contains probably mixed sulphates, such as magnesium sulphate, sodium sulphate, potassium sulphate, and calcium sulphate." It is natural to conclude that the decomposition of iron sulphide in the original sands may have converted much of the chloride into sulphate. Sulphuric acid is also a product of the combustion of coal, which would account for the presence of a certain amount in localities like those from which these muds were obtained. But the point of interest is the probable substitution of sulphates for chlorides, from whatever source the acid may have come. This consideration shows that there may have been originally more sea salt in a sedimentary rock than is indicated by the quantity of sodium chloride it now contains.

Another point to be noticed is, that the amount of salts in the ancient rocks being so near that in rocks now presumably being deposited, shows that the ocean was about as salt then as it is now, and consequently not much additional sodium can have accumulated in it during the long ages since Silurian times.

In the 18th annual report of the U.S.A. Geological Survey[1] upwards of sixty analyses of well waters are recorded in Indiana and Ohio. In the artesian wells sodium chloride is very abundant, to the amount of 1,000 to 3,000 grains to the U.S.A. gallon. These waters appear to be found in sedimentary rocks. In the 19th report[2]

[1] 1896–7, pt. iv, p. 500.
[2] 1897–8, p. 650, "Rock Waters of Ohio."

we read: "Water from a greater depth [not specified] holds dissolved chlorides as well. Chloride of sodium is by far the most common, but chlorides of magnesium and calcium are often added. Such waters are usually called saline. The presence of chlorides is seldom shown in waters at less than 100 feet in depth. . . ." "It is very rare that the drill descends to 300 feet without encountering saline water." These waters are from Silurian beds.

The conclusion to be drawn from these remarks is, that some of the sodium found in river waters may probably be derived from the "fossil waters" of old sea muds, and if that is the case, it is in circulation from the ocean to the stratified rocks and back again. No doubt much sodium may find its way into rivers immediately from the felspar of rocks, but we are not justified in crediting all the sodium conveyed to the ocean as having been supplied *de novo* in that manner. This consideration would lengthen Professor Joly's estimate of the world's age by an unknown period.

An enquiry not without interest may be made as follows:—Supposing the whole of the land area to consist of granite; for how many years would a foot thickness of the land supply the sodium as carried down by the rivers at the present rate? Mr. Merrill's book supplies the data to answer this question.[1] He describes a section where solid granite occurs at the bottom, and, after passing through an intermediate stage of weathering, is disintegrated into sand at the surface. It appears legitimate to assume that this process of disintegration keeps pace with the denudation of the surface. Mr. Merrill says that the solid granite, in the process of disintegration into the residual sand, loses 28·62 per cent. of its soda. Now the weight of the sodium is the weight of the soda *minus* the weight of the combined oxygen, so that it will be 23/31 the weight of the soda. Also he tells us that the weight of the soda is 2·68 per cent. of the solid granite; and according to Mallet a cubic foot of granite weighs 198·34 pounds.

With these data it appears that the weight of the sodium in a cubic foot of granite is 0·00047029 of a ton.

Accepting Professor Joly's figures, the land area in square feet will be $55{,}814{,}000 \times (5{,}280)^2$, which gives us the volume of a layer a foot thick covering the land area; also the weight of the sodium annually discharged by the rivers is 157,267,544 tons. Dividing this by the volume of the one foot layer multiplied by the weight of sodium in a cubic foot, we get 1/5000 of a foot of granite as competent to supply the sodium of the rivers in the annual process of disintegration.

We may hence conclude that, if the land area consisted of granite, the rate of denudation would be one foot in 5,000 years. Sir A. Geikie, in his "Text Book of Geology" (p. 444), accepts one foot in 6,000 years as a probable mean for the rate of denudation. It is certainly remarkable that the result we have obtained comes near this. But when we remember that but a small portion of the land surface consists of crystalline rocks, and that the mean

[1] "On Rocks and Rock Weathering," p. 209.

percentage of soda in sedimentary rocks is only 1·47 (p. 44), it is obvious that a much higher rate of denudation would be required to yield annually by decomposition of such rocks the amount of sodium carried down by the rivers. The conclusion will be that, if one foot denuded in 6,000 years is near the truth, the sodium in the rivers must have some further source than the soda which forms a mineral constituent of the surface rocks, and that this additional soda is probably derived, as already suggested, from "fossil" sea-water. Ought not also some allowance to be made for the soda introduced into rivers by human agency?

The style of the paper leaves here and there a little to be desired in respect of clearness; for instance (p. 47), "We can apply to the mean analysis of the sedimentaries on the one hand, and to that of the original crust on the other, to arrive at a rough estimate of the loss of entire rock by solution in the process of formation of the former." Again (p. 46), "We accept one mile deep of these [detrital sediments] on the land, and confining ourselves to purely detrital siliceous sediments, assume that as much as 10 per cent. of what is on the land is in the sea [!], or say a total of 1·1 mile deep over the land area."

In this important essay Professor Joly has opened up an entirely new line for the investigation of geological time. It is too soon to pronounce whether his numerical estimate is fully to be relied upon, until it has been a little while before the scientific world. His period of between 80 and 90 million years will perhaps satisfy geologists as being sufficient. The leading physicists, on the other hand, are disposed to grant us a good deal less time.

O. Fisher.

Harlton, Cambridge.
January 22, 1900.

II.—The Fauna of the Silurian of Podolia.

Fauna sīluriĭskīkh otlozheniĭ podol'skoĭ guberniĭ. Die Fauna der Silurischen Ablagerungen des gouvernements Podolien. By P. N. Venyukov (Wenjukow). Mater. Geol. Russlands, XIX, pp. 21–266, pls. i–ix; November, 1899.

PODOLIA, which lies to the south-west of Kiev, is bounded on the south by the Dniester and on the west by Galicia, and is drained by a river beloved of every schoolboy—the Bug. The Silurian rocks are all in the south-west of the province, adjoining the similar formations of Galicia. The present work by Professor Venyukov of Kiev describes the fauna of these rocks, unfortunately for us, in Russian; but the broad results may be gathered from the short abstract in German, while the new species, of which there are not a few among corals, brachiopods, molluscs, and ostracods, may to some extent be identified from the plates. The Silurian geologist will certainly have to read the abstract, and the specialist in palæontology must get the Russian descriptions translated for him. Here we give only the main conclusions.

The Silurian rocks of Podolia consist chiefly of limestone, and may be divided into three series (*Horizonte*), each characterized by a more or less independent fauna, which developed and altered during the deposition of the series. The lowest series, which occurs in the south-east of the Silurian area, near Studenitza, is very poor in corals and gasteropods, but rich in brachiopods, especially Atrypidæ and Leptænidæ. Among the characteristic species are *Strophomena antiquata, Atrypa cordata, A. imbricata, A. Barrandei, A. Thisbe, Pentamerus linguifer*, and *Glassia compressa*. This is correlated with the Wenlock Shale, and with bed *c* of Lindström's Gotland scale. The middle series has a wider extent, and is exposed along the north bank of the Dniester. It is very rich in corals, such as *Cyathophyllum articulatum, Ptychophyllum truncatum, Rhizophyllum gotlandicum*, while gasteropods of the genera *Oriostoma* (esp. *O. discors, O. globosum*), *Murchisonia*, and *Pleurotomaria* are characteristic and abundant. The brachiopods are represented chiefly by Rhynchonellidæ and Pentameridæ. The series is clearly capable of further subdivision, but in the main is correlated with the English beds from Wenlock Limestone to Aymestry, and with *d, e, f* of Gotland. The uppermost series occurs towards the north of the area, near Dumanov and Kamenez-Podolsk. Brachiopods preponderate, and among the species may be noticed *Spirifer Thetidis, S. robustus, Rhynchonella nympha, R. Hebe*, and *Atrypa sublepida*. There are scarcely any mollusca and few trilobites; but there are some ostracods and the characteristic *Eurypterus Fischeri* and *Scaphaspis obovatus* (?). As local developments are beds of crinoid-limestone, in which *Crotalocrinus rugosus* is the only recognized species. A similar occurrence is characteristic of the Gotland horizons *g* and *h*, with which this is correlated. Its English representatives are the Upper Ludlow and Passage Beds.

It is clear that for the greater part of Silurian time the Podolian area formed a part of the great northern basin in which the rocks of England, Gotland, and North-West Russia were deposited. It was, however, connected with the Bohemian basin, and this connection increased until in Lower Devonian time the Podolian sea formed a link between Bohemia and the Ural basin. F. A. B.

III.—Beiträge zur Kenntniss des Sibirischen Cambrium. Von Eduard von Toll. Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg. Série viii, vol. viii, No. 10, 1899.

Contributions to a Knowledge of the Siberian Cambrian. By E. von Toll. 4to; pp. iv + 57, with 9 woodcuts and 8 plates.

IN this memoir Baron von Toll records the discovery of beds of sandstone, shale, and limestone, with Cambrian fossils, in several localities in Eastern Siberia widely separated from each other, which seem to indicate the existence in this region of an extensive basin of Cambrian deposits. The rocks have previously been regarded, owing to an erroneous determination of some imperfect fossils,

as of Devonian, Carboniferous, and Triassic age. The strata are principally exposed in the banks of the great rivers, and fossils have been found in the following localities: (1) Torgoschino, near Krasnojarsk on the Yenesei, 56° N. lat., 93° E. long.; (2) on the right bank of the Vilyui, 63° N. lat., 115° E. long.; (3) on the Olenek, in 70° N. lat., 120° E. long.; and (4) on the Lena, between Oleminsk and Yakutsk, in 64° N. lat., 128° E. long.

From limestones on the Lena the author describes two species of *Ptychoparia* related to forms in the *Olenellus* zone of North America; three new species of *Microdiscus*, two of which approach closely to American forms; *Agnostus*, sp.n.; fragments of a doubtful *Olenellus*; *Kutorgina cingulata*, Billings; an *Obolella* related to *O. chromatica*, Bill.; and an undetermined *Hyolithes*.

The beds on the Olenek contain *Bathyuriscus Howelli*, Walcot, a Middle Cambrian species found originally in Nevada; *Agnostus Czekanowskii*, Fr. Schmidt; and some worm tracks. From the Vilyui Fr. Schmidt has already described *Anomocare Pawlowskii* and *Liostracus? Maydelli*.

From limestones at Torgoschino on the Yenesei two species of Trilobites, *Proetus Slatkowskii* and *Cyphaspis Sibirica*, had been described by Fr. Schmidt: the former of these is now determined by the author to belong to the Cambrian genus *Dorypyge*, Dames, and the latter with some doubt to *Solenopleura*, Angelin.

The Yenesei rocks likewise contain numerous representatives of the widely distributed Cambrian family of the Archæocyathinæ. The author describes six species of *Archæocyathus*, Bill., three of which are new, and three considered to be identical with species from the Cambrian rocks of Sardinia. Of the allied genus *Coscinocyathus*, Bornemann, seven species common to the Sardinian rocks and one new are recognized, and there is also a doubtful form of *Protopharetra*, Bornemann. The Yenesei examples of this family, like those from Sardinia, appear to be enclosed in a very hard limestone, so that they can be studied only in sections; consequently the recognition of specific characters is very difficult, and complete identification of species, as the author acknowledges, is hardly to be expected.

A new genus, *Rhabdocyathus*, is also proposed: it agrees, in the laminate character of the wall, with *Spirocyathus*, Hinde, but it possesses neither septa nor dissepiments, and the space between the inner and outer wall layers is traversed by tubes which open on the exterior surface as rows of pores. The author considers that this form represents a simpler type of the family than any hitherto known, and, further, that it furnishes a clue to the systematic position of the group, which, as is well known, is not as yet by any means settled. The Archæocyathinæ have been in turn referred to siliceous sponges, foraminifera, and perforate corals, but their resting-place in any one of these divisions has not received the general support of palæontologists. Von Toll puts forward a fresh suggestion, namely, that they are possibly Calcareous Algæ, whose nearest relations are to be found in the Tertiary genus *Acicularia*,

D'Archiac, and the existing *Acetabularia*, Lamx. Whatever may be the final conclusion respecting the nature of the Archæocyathinæ, their significance as characteristic fossils of Cambrian strata is further manifested by their occurrence, in association with *Dorypyge*, in Eastern Siberia.

It may be hoped that the author's anticipations of fresh discoveries of fossils in these ancient rocks in the works for the great Siberian railway, now in progress, will be fully realized.

G. J. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—January 10, 1900.—W. Whitaker, B.A., F.R.S., President, in the Chair. The following communications were read:—

1. "On a Particular Form of Surface, the Result of Glacial and Subaerial Erosion, seen on Loch Lochy and elsewhere." By Dr. W. T. Blanford, F.R.S., Treas. G.S.

This form of surface, first noticed by the author on Lake Como, was afterwards observed in the Great Glen of Scotland and in British Columbia. It consists of an almost even plane sloping at a moderate or high angle, and cut at intervals by small ravines or channels. The sides of the Great Glen have been planed by glacier-action to a greater extent than usual, and between Loch Lochy and Loch Oich, near Laggan, the sides of the Glen have a regular and flat slope of over 35° up to about 1,000 feet above sea-level. Numerous stream-cut channels draining down this slope are, on an average, not more than 10 to 15 feet deep, but some quite exceptional examples may be 50 feet deep; these channels occupy less than a fourth of the surface. In addition there are larger glens which, although they run out into shallow ravines where they cut the sloping side of the Great Glen, are frequently 500 feet in depth among the hills. If these were ordinary stream-valleys before the Glacial Period, the cutting away of the ridges separating them to the extent of at least 250 or 300 feet must be attributed to glacial erosion on the sides of the Great Glen. The erosion of the small ravines in the glacial slope must have been effected by streams in post-Glacial times, and the measurement of their rate of erosion might be expected to throw light on the amount of time which has elapsed since the Glacial Period in this district. "The general effect produced by the whole evidence is . . . . the small amount of denudation that has taken place since the Great Ice Age, and the necessary deduction that no great period of time, measured in years, can have elapsed between the Glacial Epoch and the present day."

2. "On the Geology of Northern Anglesey." Part II. By C. A. Matley, B.Sc., F.G.S.

The present paper deals in the first place with the stratigraphy of the Northern Complex. The following table shows the succession of the rocks in descending order :—

C. The Llandeilo Strata.

	Feet.
C *d*. Black argillaceous shales	40 ; top not seen.
C *c*. Ironstone, in part oolitic	20
C *b*. Grey quartzose shales or slates, striped by thin, black laminæ	150
C *a*. 2. Pale conglomerates and grits	500
1. Red-purple conglomerate	180

B. The Llanbadrig Series, about 1,000 or 1,500 feet ; apparent order :—

B *f*. Quartzite.
B *e*. Pebbly slates.
B *d*. Slates with grit and quartzite bands.
B *c*. Quartzites, shales, and some limestone (Porth Padrig, etc.).
B *b*. Limestone (as at Trwyn y Parc).
B *a*. Grits and slates, usually smashed to a crush-conglomerate.

A. The Green Series.

Greenish and bluish slates (of the Northern Complex).

The rocks strike east-south-east, and dip usually at a high angle northward ; a well-marked transverse fault divides the complex into western and eastern portions. The Llandeilo rocks occupy four strips of ground in the west and three in the east, but the full succession does not occur in any one of these outcrops. The effects of compression are much marked in the purple conglomerate ; the matrix is dragged out along small shear-planes, and the pebbles are stretched into phacoids, slip-faulted, and their extremities tailed out. A deceptive appearance of unconformity is also produced at the junction of grits and shales. Fossils are found in some of the rocks. The Llandeilo rocks are of importance, as they reveal the existence of at least four shattered synclines, usually faulted, and probably all overthrust on their northern boundaries.

No fossils have been found in the Llanbadrig rocks, and no more definite assertion of their age is possible than that they are pre-Llandeilo. They are newer than, and their base may be conformable with, the Green Series ; but as fragments almost certainly derived from the latter series have been found in the highest zones, the relation between the two series is more likely to be that of an unconformity. The Llandeilo rocks contain fragments of limestone and pieces of quartzite ; but in spite of this evidence in favour of unconformity between the Llanbadrig and Llandeilo rocks, the basal beds of the latter are found to cling closely to the highest quartzite of the Llanbadrig Group.

The quartzites are remarkable in the fact that they frequently contain patches of limestone, apparently deposited with them, and that they vary rapidly in thickness from about 30 to 200 feet at Craig Wen, where this variation is correlated by an inverse variation in the conglomerate. Although earth-movement may be partly responsible for this variation, some further explanation appears requisite, and this may possibly be furnished by erosion of

the quartzite. The overthrusting force appears to have come from a direction somewhat east of north.

The igneous rocks are dealt with in two groups: those older and those newer than the earth-movement. To the former belong granite, serpentine, and its associates, and basaltic dykes. In each area where they occur the serpentines are associated with masses of a peculiar purple limestone not known elsewhere; they also contain bands of ophicalcite, and schistose structures are common in the rocks. The later dykes belong to an acid and a basic set; the latter show some evidence of a minor movement, such as faulting and a little shearing. The acid dykes are microgranites, granophyres, and quartz-porphyries. In some cases the dykes are composite, the acid material being the older and the basic the later constituent. As a rule, the basic material invades the edge of the dyke; but in one case it has invaded the joints and cracks and caught up fragments of the acid rock.

3. "The Formation of Dendrites." By A. Octavius Watkins, A.R.S.M., F.G.S.

If two plane-surfaces be separated by a film of suitable plastic material, and one surface be rotated slowly on the other through a small arc, the plastic material collects into branching forms similar to the structure of dendrites. The dendritic form starts from the part farthest from the axis, and the flow of material is from the smaller to the larger branches, the smaller uniting to form the larger. The author explains dendritic structure by the formation of a fissure in rock which becomes filled with a thin film of dendritic material; if the fissure is slowly widened, the dendrite starts where the widening commences, coinciding dendrites being formed on each wall. This theory is in accordance with many of the characters of dendrites, such as their method of occurrence, the nature of the material, and their uniformity in thickness.

II.—January 24th, 1900.—W. Whitaker, B.A., F.R.S., President, in the Chair. The following communications were read:—

1. "Fossils in the University Museum, Oxford. II. On two New Genera and Species of Crinoidea." By W. J. Sollas, M.A., D.Sc., LL.D., F.R.S., V.P.G.S., Professor of Geology in the University of Oxford.

The first genus and species are founded on two calyces in the University Collection and three in the British Museum; all the specimens come from the Carboniferous Limestone. The arms and stem are at present unknown. The genus in general character and structure recalls *Platycrinus*, but the incorporation of the costal and distichal plates in the calyx affords a very obvious distinction. The analysis of the calyx, however, suggests the Melocrinidæ, from the members of which it is chiefly distinguished by the comparatively small size of the costal and distichal plates. The new genus is a truly annectant form uniting the Melocrinidæ and the Platycrinidæ, and may be indifferently associated with either.

The second genus and species are founded on a specimen in the Grindrod Collection, obtained probably from the Silurian rocks, but from a locality not known, possibly Dudley. In general appearance it resembles an elongated form of *Pisocrinus*, particularly in its calyx, but the arms are those of a Heterocrinid. This conjunction of characters, though rendering necessary a revision of the definition of the Pisocrinidæ, cannot be regarded as bringing this family appreciably nearer to the Heterocrinidæ, which are fistulate, while the Pisocrinidæ, so far as known, are not.

2. "Fossils in the University Museum, Oxford. III. A New Worm-track from the Slates of Bray Head, Ireland; with Observations on the genus *Oldhamia*." By W. J. Sollas, M.A., D.Sc., LL.D., F.R.S., V.P.G.S., Professor of Geology in the University of Oxford.

The curious markings known as *Oldhamia* have not been hitherto recorded from other than the lower Palæozoic rocks, although they have a wide distribution in space, being found in Ireland, in the Ardennes, in Brabant, in America, and possibly in Norway. While the organic nature of *Oldhamia* was scarcely a matter of doubt in the minds of the earlier writers, there existed a great diversity of opinion as to its place in the organic world, and it was placed by different observers among polyzoa, hydrozoa, and plants, respectively. The microscopical observations made by the author prove that *Oldhamia* is not the remains of an organism, but merely a marking in the rock, though one which might be, nevertheless, of organic origin. Certain markings formed in the mud at Portishead, by the feeding habits of a small burrowing crustacean, bear a considerable resemblance to specimens of *Oldhamia*; but a stronger resemblance to the new species described in this paper is found in Nathorst's figures of the impressions made by one of the two recent worms *Glycera alba* or *Gonidia maculata*. Professor Joly's observation that markings of *Oldhamia antiqua* always occur in relief, while those of *O. radiata* are depressions, might suggest that while one set of markings was produced by the animal when feeding, the other was connected with its castings of excrementitious matter. This explanation is open, however, to several objections, and the author is inclined to believe that these species of *Oldhamia* are the traces of some kind of siphonaceous alga: the cavities left by their decay were subsequently filled in by sediment under pressure. If the upper surface of *O. antiqua* were more resistant than the lower, this might account for its preservation in relief. The microscopical examination of slate containing *Oldhamia* affords evidence of original and secondary structures which have an important bearing on this question.

3. "Contributions to the Geology of British East Africa. Part II: The Geology of Mount Kenya." By J. W. Gregory, D.Sc., F.G.S.

The three main zones of Kenya are characterized by different geological features. The long slope of the forest-belt consists in the main of volcanic ash, though the remains of secondary parasitic

craters occur in it. The Alpine zone consists of coarser ash, agglomerates, and tuffs, interbedded with lava-flows and traversed by numerous dykes, with the remains of some secondary centres of eruption. The third zone, or central peak, consists of the plug which choked the central vent, of beds of agglomerate, and the thick proximal ends of the great lava-flows.

The rocks of the central core comprise an olivine-anorthoclase-nepheline-syenite with ægyrine, and a black glassy lava with numerous white phenocrysts of anorthoclase; this rock is allied in some respects to the pantellerites, but receives a special name both here and in its occurrence in lava-flows.

The dyke-rocks fall into two categories—a series of phonolites, and one of basalts and dolerites. One, at least, of the dykes is compound, including both these rock-types. The basic group ranges from basalts with little olivine to coarsely crystalline dolerite rich in that mineral.

The lavas belong to three main groups: (1) those of the nepheline-syenite series, (2) the phonolites, and (3) the basalts. The oldest lavas appear to be the phonolites, but they and the first group of lavas seem to have overlapped in age; the olivine-basalts, which reach the surface from a zone of secondary craters in the Alpine zone, are the latest in date. The first group of lavas are rhyolitic in aspect, and consist of a brown or green glass in which are embedded phenocrysts of anorthoclase, and green needles which show the optical characters of ægyrine. As these rocks do not conform to Rosenbusch's definition of pantellerites, a new name is proposed for them; the author considers that the pantellerites may be liparitic equivalents of the dacites, while these Kenya rocks correspond with the nepheline-syenites. The structure of the phonolites is trachytic, the groundmass including abundant small, lath-shaped plagioclases; nepheline is not very abundant, and occurs in larger crystals than the other constituents, the chief of which is ægyrine. The basalts are often vesicular and columnar, and contain olivine, augite, magnetite, and apatite often in a glassy groundmass.

The pyroclastic rocks vary in texture from coarse to fine; they contain blocks of all types of the lavas, and also large crystals of anorthoclase.

The nepheline-syenite is the most deeply-seated, holocrystalline rock found on Kenya; and the mountain appears to represent a single, ancient, dissected, volcanic mass, with a shorter geological history and a narrower range of rock-types than its great companion volcano, Kilima Njaro. The author gives reasons for considering that all the different rock-types present may have resulted by differentiation from the olivine - anorthoclase - nepheline - syenite magma, although this involves the conclusion that in some cases the basic materials must have concentrated in the glass and solidified after the formation of the felspars.

4. "Contributions to the Geology of British East Africa. Part III: The Elæolite-Syenite and Fourchites intrusive in the Coast Series." By J. W. Gregory, D.Sc., F.G.S.

The rocks described in this paper were given to the author by Mr. C. W. Hobley. Mount Zombo, situated in long. 39° 13′ E. and lat. 4° 26′ S, and 1,519 feet high, is a massif of coarse-grained elæolite-syenite, consisting of anorthoclase, elæolite, usually allotriomorphic, and ægyrine. The rock must occur in the belt of Duruma Sandstone, unless the fossiliferous Jurassic shales run westward up the low valley of the Umba River. Associated with this massif is a series of dykes belonging to the olivine-less variety of monchiquites known as fourchites. Their phenocrysts consist of plagioclase, probably oligoclase, hornblende, and ægyrine, but augite and ilmenite are also present; the groundmass contains a certain amount of analcite.

Unfortunately there is some doubt as to the exact age of the Duruma Sandstone into which the fourchites are intrusive. The author gives an account of the different opinions as to the age of these rocks; the evidence at present available is only sufficient to prove that they are post-Carboniferous and pre-Callovian. The sedimentary series on the coast-lands of British East Africa and Usambara, in his opinion, may be previously arranged as follows:—

5. Pleistocene reefs, limestones, alluvium, and laterites.
4. Jurassic shales and sandstones; Kimeridgian, Oxfordian, and Callovian.
3. Possibly a pre-Jurassic part of the Duruma Sandstone.
2. Magarini sandstones; ? Triassic.
1. Sabaki shales; Upper Carboniferous.

It is therefore probable that the igneous rocks are not older than the early Mesozoic, and may be Jurassic or post-Jurassic.

III.—February 7, 1900.—W. Whitaker, B.A., F.R.S., President, in the Chair. The following communications were read:—

1. "Foraminifera from an Upper Cambrian Horizon in the Malverns." By Frederick Chapman, A.L.S., F.R.M.S. (Communicated by Prof. T. T. Groom, M.A., D.Sc., F.G.S.)

The foraminifera described in this paper were found in a shaly limestone which Professor Groom obtained "from the débris of a small ridge composed of black shales, with intercalated basalts, which forms a spur on the north-west side of Chase End Hill. The rock belongs to the well-known and widely-spread zone of *Sphærophthalmus*, *Peltura*, and *Ctenopyge*, which in Britain forms the upper half of the Dolgelly Beds or Upper *Lingula*-Flags." The specimens have been sliced, and have yielded a few forms other than *Spirillina*; sections of echinoderm-spines, ostracod-tests, and occasionally sponge-spicules (?) are also to be seen in the slides. The tests of the foraminifera are infilled with a crystalline substance.

The following species are mentioned: *Lagena lævis*, Montagu, *L. apiculata*, Reuss, *L. ovum*, Ehrenberg, *Nodosaria pygmæa* (?), Terquem, *N. abnormis* (?), Reuss, *Marginula soluta* (?), Reuss, *Cristellaria acutauricularis* (?) (Fichtel & Moll); and a new species of *Spirillina* is described. The *Spirillinæ* are in a good state of preservation; and the valves of mollusca, cut through in section, are sometimes seen to be quite filled with the tests of this genus.

A record is given of some of the earliest known foraminifera, including the somewhat doubtful forms described by Cayeux from pre-Cambrian rocks in Brittany, those by Ehrenberg from the so-called 'Silurian Clay' near St. Petersburg, by W. D. & G. F. Matthew from the rocks bearing the *Protolenus*-fauna in New Brunswick, by Keeping from the shells above the Bala Limestone near Welshpool, by Blake from the Llandovery of Cwm Symlog, by Brady from the Woolhope Limestone of the Malverns, and by Terquem from the Upper Silurian rocks of Indiana. The author has also frequently met with *Lagena* in the Wenlock Limestone of Shropshire.

2. "Bala Lake and the River-System of North Wales." By Philip Lake, M.A., F.G.S.

In this paper the author begins by showing that topographically Bala Lake belongs to the same valley as the River Wnion—the valley of the Bala Fault; and he believes that the whole drainage of the valley flowed originally south-westward, and entered the sea near Barmouth.

He then examines the possible outlets, and shows that the lake is probably rock-bound in all directions except towards the south-west, where there is no conclusive evidence.

He describes the faults which occur near the watershed that separates the Wnion from the streams flowing into Bala Lake, pointing out that they are closely related to the form of the valley, and that the watershed coincides with a transverse line of fault. From this he infers that the formation of the lake is possibly due to earth-movements.

The watersheds of several other similar valleys are examined, and are shown to lie in one straight line; whence it is concluded that they must have been produced by some general cause, probably a slight differential movement.

The general drainage-system of North Wales is next discussed. Attention is drawn to the existence of a series of long and nearly parallel valleys running from north-east to south-west, which divide the region more or less completely into a number of strips. The drainage of each strip is now independent, and flows in most cases into the long valley lying south of it. But from the fact that the chief streams in each strip have their representatives (flowing in the same line) in the adjacent strips, it is concluded that before the formation of the long valleys the streams were continuous.

The centre from which these streams radiate lies in the high ground near the sources of the Conway; and the author believes that this was the centre of an original radial system of drainage, and that this radial system was subsequently broken up into sections by the formation of the long valleys which now run from north-east to south-west—each of these long valleys carrying away the drainage of one of the sections. He attributes the formation of the long valleys to faulting.

CORRESPONDENCE.

RAILWAY SECTIONS IN AYRSHIRE AND LANARKSHIRE.

Sir,—At present there are some railway sections through Drift in the line being constructed from Darvel, in Ayrshire, to Strathavon, in Lanarkshire, which, I think, show features *demonstrative* of a depression of the land, and the marine origin of at least part of the Drift beds. Lately, with two friends (it was my fourth visit to the locality), I examined minutely one of these sections, 500 to 600 feet above sea-level (estimated from a bench-mark). This cutting is to be a deep one, and is being taken in two 'lifts'; about 200 yards of the upper lift can at present be examined, but it is much longer, part of the slope being already pick-dressed. The section is almost horizontal for the above-mentioned distance, and very regular—not at all twisted or disturbed, as is the case with many parts of the Drift. It is about two miles east of Darvel. The following beds are exposed:—

1.	Sand and gravel, stratified	15 feet.
2.	Stony Boulder-clay with large blocks	6 ,,
3.	Laminated clay with few stones and large blocks ...	5 ,,
4.	Stony clay	3 ,,
5.	Sharp sand, not cut through.	

In bed 1, I observed a long boulder of Matstone Hill granite, quite in a vertical position. In beds 2, 3, and 4, long boulders were obtained during the progress of the cutting, in a similar position. In the laminated bed 3, a large striated boulder of white sandstone is at present to be seen, measuring four feet in diameter. It has clearly *fallen into the clay* when the latter was in a *soft state*, as the laminæ at the bottom corners of the block *are bent down under it*, showing that the block in falling has made a small indent in the laminated clay. They (the laminæ) also curved over the top of the block.

Another interesting feature was the depressions or ruts in the stony clay bed 2, these being invariably filled more or less with laminated clay. A number of shell-fragments *with the epidermis* were picked out by us from the stony clay, and from the laminated bed we secured a perfect valve of *Leda parvula*. (I may say that in this district marine shells are frequent in certain parts up to 700 feet above sea-level. See suppl. to vol. xi, Trans. Geol. Soc. Glasgow, p. 59.)

The boulders in the sections of the railway at this part are a variety of porphyrites (igneous rocks with conspicuous felspar, a 'Survey' term), amygdaloids, felstones (igneous fine-grained rock, a 'Survey' term), sandstones, dolerites, a few limestones; Matstone Hill granite, a moderately coarse-grained reddish granite, being not infrequent, the parent rock occurring fully two miles to the south and on the opposite side of the Irvine Valley to the railway sections.

Not only the Boulder-clay, *but a sharp grey sand bed* also shows very distinct *jointing*. The joints in a *sand-pit* 200 yards north of the railway were very conspicuous, and had attracted the attention of the workmen in the pit, who called them *water-backs*. Workmen's

terms are generally pretty expressive. In solid rocks water often issues from joints.

We went on to Londoun Hill. This hill is not named on Sheet 23; it is just above the house named Backhill on the western edge of the map. It is composed of large vertical columnar felstone.

To the east and south-east of this hill the 'Survey' have shown a 'terrace of marine drift' and an 'old sea beach.' Lately I observed that the talus of large blocks from the hill had *fallen down upon the top of the* 'marine *drift*,' so that the great vertical cliff on the south side of the hill was very likely *the work of the waves*, assisted perhaps by shore-ice, for much of the 'felstone' in the drift may have come from this hill, it being the only felstone rock within many miles of this district.

The 'marine terrace' is 700 feet, and the top of Londoun Hill 1,034 feet, above sea-level.

The facts given in this letter speak, I think, pretty plainly. The Drift beds here are clearly *water deposits*, and that 'water' was the sea. The blocks and stones in both the stony and laminated clay were clearly dropped into the clay from floating ice. In bed 2 (the stony Boulder-clay), there are frequent indications of *stratification*, and those lines have a steady, *gentle* dip of five to ten degrees towards the east, or up the Irvine Valley. This long section has been exposed to the weather for about six months; the clay has not slipped, and the rain-washed face of the drift can be read like a book. There are many well-striated stones and boulders *lying in all directions*, long ones even vertical, but quite as many which show no striations. The ruts in the stony clay bed 2 were probably produced by floating ice grating on the sea bottom, and these have formed *sheltered hollows* in which laminated clay has been deposited.

J. Smith.

Monkredding, Kilwinning.

SOME SNOWDON TARNS.

Sir,—Will you permit me to correct a mistake in my paper on "Some Snowdon Tarns." The depression at 250 yards from the present outlet of Llyn Llydaw is in a N.N.E. direction therefrom, not N.N.W. as I had erroneously written. J. R. Dakyns.

Snowdon View, Nant Gwynant,
Beddgelert, Carnarvon.
February 19, 1900.

OBITUARY.

GEHEIMRATH PROFESSOR DR. GEINITZ,

For. Mem. Geol. Soc. Lond.

Born October 16, 1814. Died January 28, 1900.

Dr. Hans Bruno Geinitz was born at Altenburg, Saxony, where he passed a happy boyhood in his father's home. The political troubles of 1830 affected the family prosperity, so that the youthful

Geinitz had to serve for four years in the shop of the Court chemist, but this did not prevent him from spending his spare time in the study of botany, chemistry, and modern languages. In 1834 a way opened for him to go to the University of Berlin, and in 1836 to that of Jena, where he graduated in 1838. Under the influence of Quenstedt, Geinitz directed his attention more particularly to the study of mineralogy and palæontology, and the subject of his graduation thesis was the Muschelkalk in Thuringia. In the same year, 1838, he went to Dresden and accepted the post of assistant-tutor in the Technical High School, with the modest salary of 150 thalers (about £22) per annum. In 1850 he became Professor at the same institution, and he occupied this position until 1894, when, owing to increasing deafness, he was obliged to resign. From 1863 to 1878 he was one of the editors of the *Neues Jahrbuch*; in 1857 he was appointed Director of the Royal Mineralogical Museum at Dresden, which may be said to owe its present flourishing condition mainly to his zeal and energy, and also the founding of the Prehistoric Museum in 1874.

Professor Geinitz was a very prolific writer on geological and palæontological subjects, and his published papers date from 1837 to nearly the latest years of his life. Though to a large extent they refer to the rocks and fossils of his native country, they yet include matters of general and permanent importance to geological science. Amongst his principal memoirs are his descriptions of the fossils in the Grauwacke formation of Saxony, which appeared in 1852; the monograph of the animal remains of the Dyas formation, 1861–62; and that on the "Elbthalgebirge," 1871–75, which contains the results of his long-continued researches into the stratigraphy and palæontology of the Cretaceous rocks of Saxony and adjoining countries. He also wrote on the fossil flora of the Hainich-Ebersdorf Coal Basin, and on that of the Coal formation in Saxony. A commendable feature in Geinitz's palæontological memoirs is the admirable manner in which they are illustrated.

Professor Geinitz was deservedly esteemed and honoured alike by the geologists of his own country and by those of other lands. He became a Foreign Member of the Geological Society of London in 1857, and was the last of those elected to this position directly without passing through the subordinate stage of Foreign Correspondent. In 1878 he received the Society's Murchison Medal.

Professor Geinitz died at Dresden on the 28th January in the 86th year of his age, and his remains were interred on the 31st, in the presence of a numerous gathering of his old students and colleagues.[1] G. J. H.

The Honorary Degree of Doctor of Laws has just been presented by the Senate of the University of Glasgow to Mr. Arthur Smith Woodward, F.L.S., F.G.S., of the British Museum (Natural History), Cromwell Road, London.

[1] Many of the facts in the above notice are taken from the *Dresden Anzeiger*, a copy of which was kindly forwarded by Miss Agnes Crane of Brighton.